Understanding your landscape's resilience: Beyond Regulation

CASE STUDY 3

Farm Type: Arable
Location: Balfour

THRIVING SOUTHLAND
Healthy people and environment, from mountains to sea

LAND & WATER SCIENCE

Understanding your landscape's resilience: BEYOND REGULATION

Prepared by

Hunter M, Kyte R, Chakwizira E, Boyce A, Hardie P,

Rissmann C, Stevenson D

Thriving Southland

www.thrivingsouthland.co.nz

Land and Water Science Ltd

Foundation for Arable Research

Disclaimer

Contents

List of Figures

List of Tables

Definition of terminology

Physiographic approach – assesses the dominant processes within the landscape that influence environmental outcomes by combining existing soil, geological, topography and climate data to understand the landscape factors controlling variation in water quality.

Landscape susceptibility mapping – takes a high-resolution physiographic approach and maps it for a property (the resolution is at paddock scale). This identifies the landscape susceptibility to contaminant loss and soil GHG emissions.

Internal rate of return (IRR) - the average rate of return on an investment.

Light Detection and Ranging (LiDAR) – remote sensing method that uses light in the form of a pulsed laser to measure ranges.

Summary

Many farmers are actively seeking opportunities to reduce their environmental impact in order to meet their own goals, as well as regulations, consumer and community expectations.

Land and Water Science Ltd (LWS) has undertaken a new, high-resolution physiographic approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scale. Landscape variability has a significant role in governing the type and severity of water quality outcomes, even when land use is the same. Landscape variability also significantly affects soil greenhouse gas (GHG) production. Linking the landscape susceptibility and farm system allows farmers to target mitigations and contaminant load reductions to reduce their environmental impact.

Method

A multi-disciplinary team met with a case study farmer. The team's expertise included landscape susceptibility mapping, water quality science and farm systems. Current options/technologies available were considered as mitigations. Options for reducing environmental impact were discussed and perspectives sought on practicality, cost, impact on farm system, and impact on environmental mitigation.

The farm

The case study was conducted on a 321ha predominantly arable farm, with dairy grazing and sheep enterprise (owned and grazed). 21.7ha is leased out for tulip production. Operated as a family-owned business, the farm is situated close to Balfour in Northern Southland, north of Gore.

The farmers have a good understanding of the changes required in farming and the related pressures (water quality, greenhouse gases and animal welfare), and have a progressive approach to positioning their business for the future.

The farmers' goals are to:

- focus on delivering cash surpluses during the current market volatility (survival!)
- consolidate their financial position, building a robust business model based on moving away from reliance on commodities where possible
- set up for succession within the family, if any of the children are interested in both farming and value-add.

The catchment

The property resides within an alluvial terrace between the Waimea Stream ~ 3.2km to the west, and the Longridge Stream, which flows along the eastern boundary. Both the Waimea and Longridge Streams flow in a southerly direction, and join into the Mataura River approximately 30km south-east of the property.

The property sits on the area known as Balfour Fan immediately south-west of the Balfour township which is approximately 5,750ha. The area is predominantly sheep, beef, deer, arable, dairy and horticulture, including mushrooms, making it a diverse agricultural landscape.

The Balfour fan is a well-known 'nitrate hotspot'[1], with some of its groundwater zones exceeding New Zealand and World Health Organisation levels for safe nitrate concentration in drinking water. Due to the nature of the aquifer not being flushed by alpine or hill country water, the concentration of nitrate in some areas continues to build.

Currently, the Toetoes Estuary, where the Mataura River discharges at Fortrose, is assessed as being in poor condition.

Landscape susceptibility

Variability in climate, topography, geology and soils significantly influences the type of contaminant and severity of water quality outcomes, even when land use is the same.

The case study farm is located predominantly within the oxidising soil and aquifer environment. Deep drainage to the underlying aquifer is the dominant hydrological pathway with some lateral flow, as indicated by the sibling class of increased lateral and overland flow. This environment has a high ability to filter and adsorb contaminants and resist erosion (minimal sediment, particulate P and microbial losses).

As the landscape has little to no ability to remove nitrogen once it has been lost from the root zone, there is a high risk of nitrate-nitrogen leaching into the shallow aquifer. Over time, nitrate can build up in the aquifer, increasing the concentration in groundwater and in-stream.

The balance of the property is located within the environment of a reducing soil oxidising aquifer. This environment occurs in lowland areas with finely textured silt or clay-rich, imperfect to poorly-drained soils and oxygen-rich (oxidising) underlying aquifers. The ability of the landscape to filter and adsorb particulate contaminants is largely dependent on how much water can infiltrate the soil.

The natural drainage of these soils has typically been modified by artificial drainage to lower the water table and improve soil drainage, reducing the occurrence of overland flow. This allows more particulate contaminants to be filtered by the soil and minimises the occurrence of runoff, but creates a pathway for water to transport dissolved (and some particulate) contaminants. These areas are also likely to have elevated soil nitrous oxide loss.

Environmental mitigation opportunities

Discussions with the farmers about landscape susceptibility risk and farm systems analysis identified opportunities to build a resilient farm system and reduce environmental impact. Changes in environmental impact were estimated using OverseerFM modelling and riparian margin calculations, and were then compared to the 2020/21 season.

Estimated change in total greenhouse gas emissions (methane, nitrous oxide and carbon dioxide combined) are reported. In addition, the estimated change in nitrous oxide emissions is identified to align with the specific opportunities in the landscape susceptibility mapping.

The high-level impact of farm system change on capital investment and farm working expenses is explored through partial budgeting. The cost of greenhouse gas emissions pricing has not been calculated; decisions are yet to be made by Government on an agricultural emissions pricing scheme.

1

https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/environment/water/groundwater/groundwater-monitoring/documents/groundwater-reports/balfour-nitrate-hotspot-2008.pdf

Mitigation options

Table 1 Mitigation options – farm system, landscape and land use

Option	Brief description	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change	Farm system/financial impact
1	Targeting nutrients applied to meet plant requirements and uptake (excluding land leased to tulips).	8% decrease	11% decrease	20% decrease	69% decrease	No change	Increase in soil testing costs. Decrease in fertiliser cost. Overall saving of $24,876.
2	Review crop rotations to reduce contaminant loadings (remove fallow period, remove winter fodder crop, add grass baleage).	3% increase	2% decrease	6% decrease	29% decrease	3% decrease	Increase of $2k in annual cost.
3	Remove/sell crop residues (rather than retaining) on 41.6ha of winter wheat.	1.4% increase	2% decrease	1% increase	5% increase	No change	Need to replace nutrients removed in the sale of straw. Need pasture in rotation to maintain soil organic matter/structure. A total revenue increase of $17,348. Highly dependent on markets/ demand.
4	Use of low solubility phosphate fertilisers.	No change	No change	No change	No change	6% decrease	Increase in fertiliser cost by $7,840. More product handle.
5	Sector 2 – prevent runoff and target tile drain outlets to intercept runoff.	No change	No change	5% decrease	No change	6% decrease	Fencing cost $3,300 Capital cost of wetland establishment estimated at $6,700.
6	Sector 3 – develop 3.3ha of wetlands and sediment traps to treat nitrates and dissolved reactive phosphorus.	No change	No change	9% decrease	No change	9% decrease	Fencing cost: $6,100 Capital cost of wetland establishment estimated at $10,000.

Option	Brief description	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change	Farm system/financial impact
7	Sector 4 – develop 7.3ha wetland on lowest point of property to capture subsurface drains from a significant portion of the property.	3% decrease	2% decrease	21% decrease	2% decrease	30% decrease	Retire 7.3ha of land currently used for grazing. Annual loss of income is $13,140. Estimated capital cost of wetland establishment is $40,000.
8	Alternative land use option to reduce contaminant loadings (establish 2ha of chestnuts).	<1% decrease	1% decrease	1% decrease	2% decrease	No change	Capital investment of $20,000 IRR of 18% (compared with winter wheat at 13%).

Scenario of bundled mitigation options

Table 2 Combined farm system, landscape and land use options

	Brief description	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change	Farm system/ financial impact
A	Mitigations combined: Option 1 – targeting nutrients applied to meet plant requirements and uptake (excluding land leased to tulips). Option 2 – review crop rotations to reduce contaminant loadings (remove fallow period, remove winter fodder crop, add grass baleage). Option 5, Sector 2 – prevent runoff and target tile drain outlets to intercept runoff. Option 6, Sector 3 – develop 3.3ha of wetlands and sediment traps to treat nitrates and dissolved reactive phosphorus. Option 7, Sector 4 – develop 7.3ha wetland on the lowest point of the property, to capture subsurface drains from a significant portion of the property.	12% decrease	15% decrease	54% decrease	94% decrease	47% decrease	Annual overall cost savings of $4,438. Estimated $66,100 capital investment into wetlands and fencing. Removing winter cropping increases risk of winter feed supply following a dry summer. Retired 7.3ha from pasture grazing.

Conclusion

The main landscape susceptibility issue on the property is nitrate-nitrite-nitrogen (NNN) leaching associated with moderately well-drained shallow soils with gravelly subsoils associated, contributing to severe susceptibility to nitrate leaching. These soils overlie an oxidising aquifer that is susceptible to NNN accumulation.

There are many options, both in landscape and farm systems, which could be implemented to reduce NNN losses from the farm to the underlying aquifer. Wetland systems, combined with reducing farm system contaminant loadings, collectively offer the opportunity to reduce environmental contamination.

Further reduction in environmental impact beyond what has been modelled is likely to require:

- further and new technologies (landscape and farm systems)
- significant land use change to a less intensive farm system.

1. The project

Many farmers are actively seeking opportunities to reduce their environmental impact to meet their goals, regulations, consumer and community expectations.

Farmers have long-term skills and knowledge balancing a range of internal and external factors in their decision-making. Uncertainty in on-farm decision-making has increased in recent years due to:

- changing consumer and processor expectations
- supply chain issues and change in cost structures
- cost of and access to capital
- concerns about climate change
- change in regulation
  - Essential Freshwater Package (including National Policy Statement and National Environmental Standard, Freshwater Farm Plans)
  - National Policy Statement for Highly Productive Land
  - Proposed GHG emissions pricing
  - Proposed National Policy Statement on Indigenous Biodiversity
- price of carbon supporting land use change.

Combining information on the landscape and farm system provides an opportunity to reduce environmental risk and inform farmer decision-making.

2. The farmers and their goals

The 320ha (309ha effective) predominantly arable farm, with dairy grazing and store sheep enterprises, leases out 21.7ha of land for tulip production. Operated as a family-owned business, the farm is situated close to Balfour in Northern Southland, north of Gore.

The farmers' goals are to:

- focus on delivering cash surpluses during the current market volatility (survival!)
- consolidate their financial position, building a robust business model based on moving away from reliance on commodities where possible
- set up for succession within the family, if any of the children are interested in both farming and value-add.

The farmers have a good understanding of the changes required in farming and the related pressures (water quality, greenhouse gases and animal welfare), and have a progressive approach to positioning their business for the future. This approach includes exploring new innovative land uses and taking the product to market.

3. Method

Variability in climate, topography, geology and soils significantly influences the type of contaminant and severity of water quality outcomes, even when land use is the same.

A multi-disciplinary team met on-farm with the farmers. Expertise in the team included landscape susceptibility mapping, water quality science and farm systems. Current options/technologies available were considered as mitigations.

During the on-farm visit, the following was discussed:

- the farmers' goals
- the farmers' background on the property and achievements to date
- catchment issues
- landscape susceptibility mapping with onsite ground-truthing
- estimated environmental losses from the farm system modelled through OverseerFM from information provided prior to the site visit.

During the visit, opportunities to reduce environmental impact were discussed. Perspectives were sought on practicality, cost and impact on the farm system, and impact on environmental mitigation. The open discussion with different perspectives allowed opportunities to be identified and refined.

4. Case study farm setting

4.1 Physical setting

Hydrology

The property resides within an alluvial terrace between the Waimea Stream ~ 3.2km to the west, and the Longridge Stream, which flows along the eastern boundary. Both the Waimea and Longridge Streams flow in a southerly direction, and join into the Mataura River approximately 30km south-east of the property.

A subsurface drain runs through the north-east corner, and an open drain runs north to south through the centre of the property (Figure 1). The property is located within the Waimea Plains Groundwater Management Zone[2].

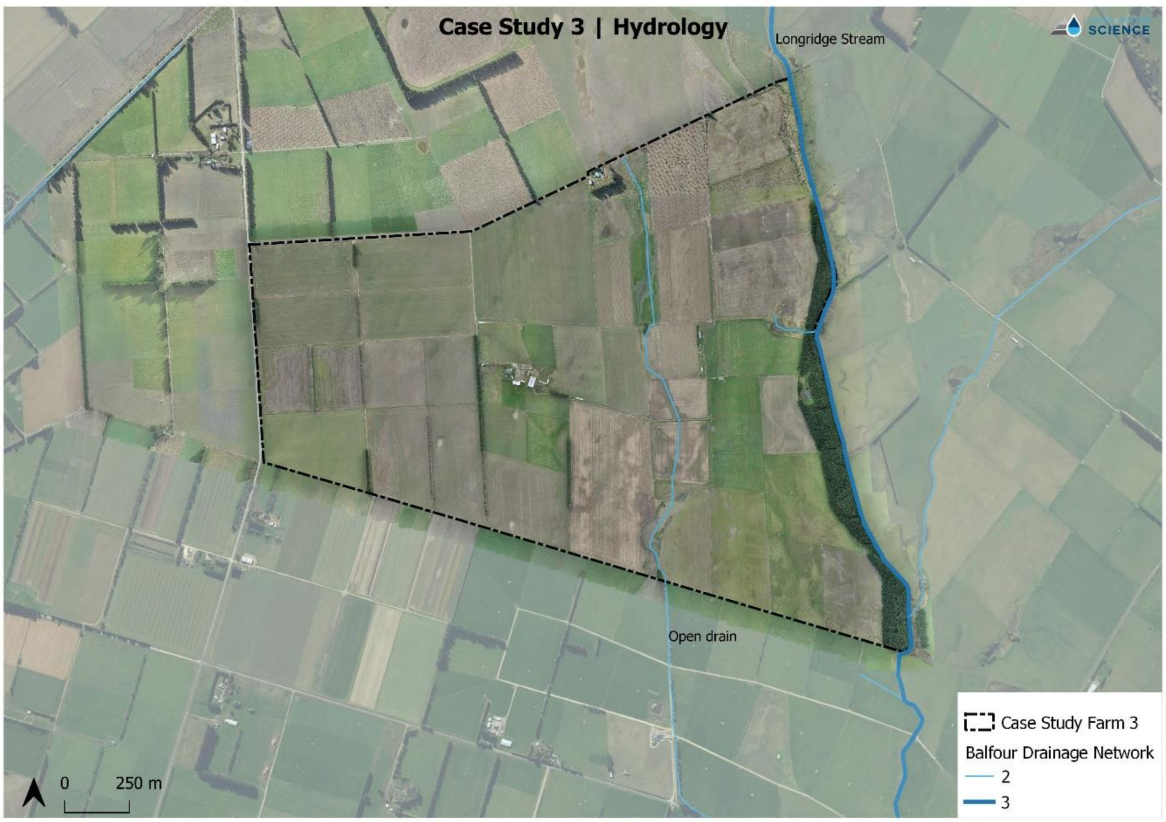

Figure 1 Streams and drains. Balfour drainage network denotes the relative size of the drainage channel/stream.

Water is the vehicle that ultimately transports contaminants from land to streams. LiDAR is now available across the Balfour catchment, and that data has been used to develop a hydrologically enforced digital terrain model to identify watersheds or basins, along with identifying nodes or discharge points, i.e. the location at which water joins an intermittent or perennial stream, or leaves the property.

[2] https://www.es.govt.nz/environment/water/groundwater/groundwater-management-zones/waimea-plains

Major drainage basins and channels

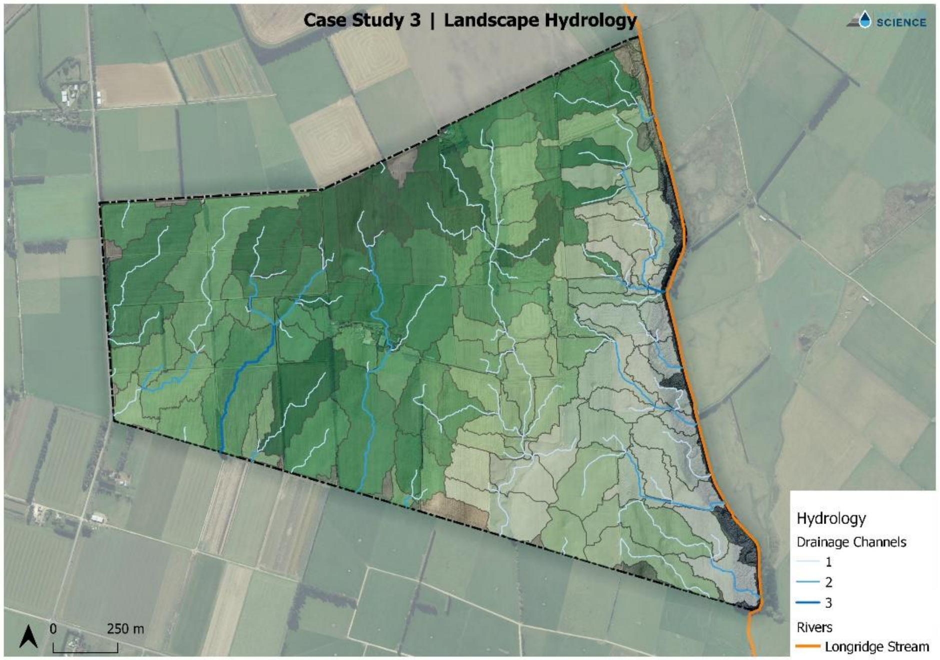

Figure 2 Case Study 3 property – major drainage basins (darker green shades reflect watersheds with higher elevation), along with the drainage channels.

Drainage junctions and discharge nodes

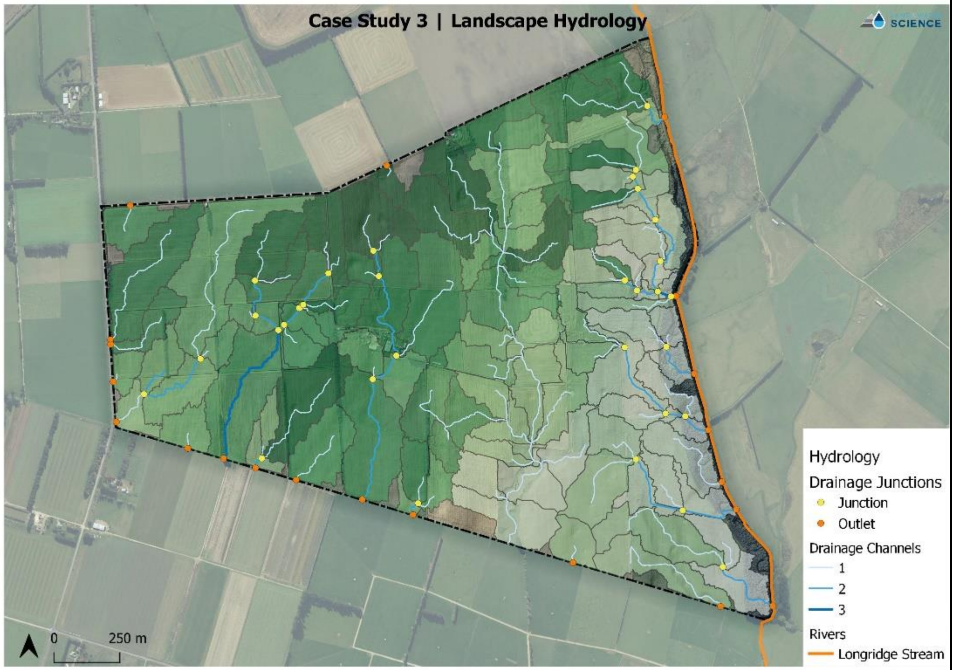

Figure 3 Case Study 3 property – discharge nodes (orange dots), where the water departs the property and junction nodes (yellow dots), the location at which water joins an intermittent or perennial drainage channel.

Topography and climate

The property is predominantly flat at an elevation ranging between 152m above sea level in the south-east corner of the property and 160m above sea level along the northern boundary and centre of the property (Figure 4).

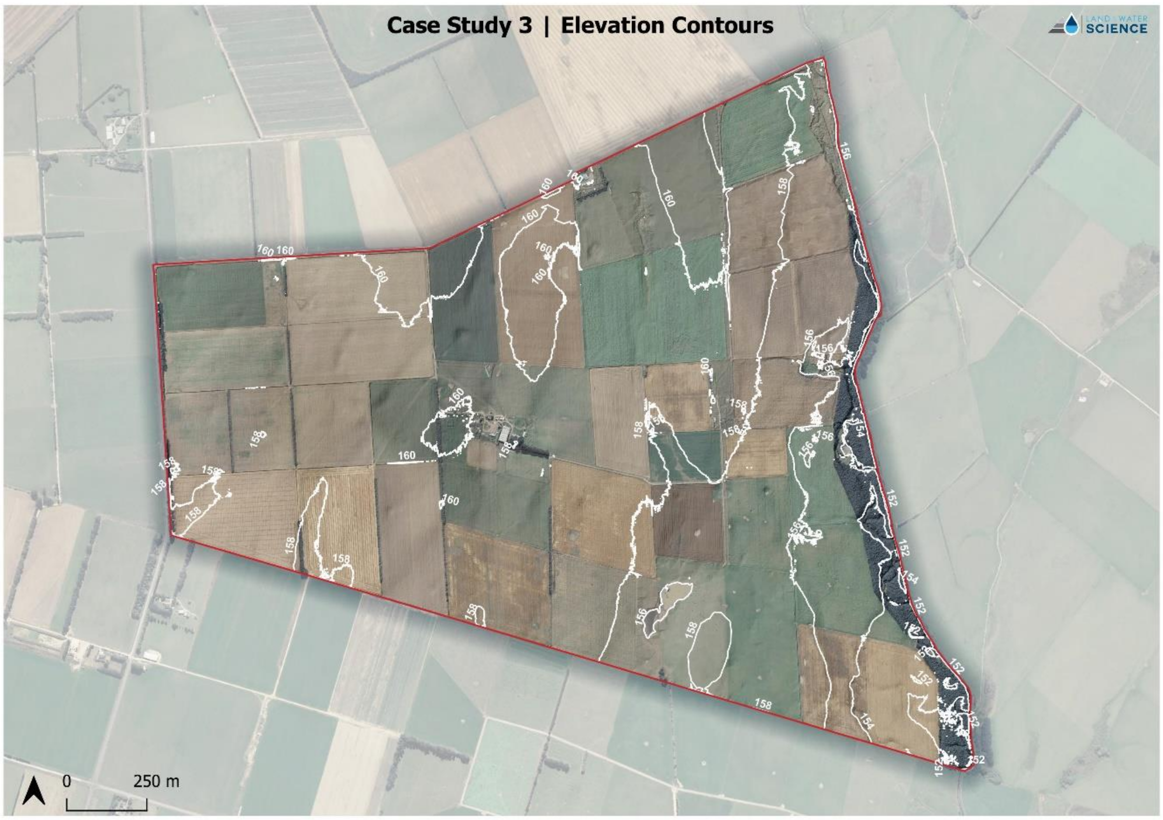

Figure 4 Elevation contours and property outline (red) in metres relative to sea level.

The Waimea Plains of Northern Southland, New Zealand, are characterised by a temperate maritime climate and local topography. Long term climate data collected between 1972 to 2016 records an average annual temperature of 10.1 °C and mean annual rainfall of 1100 mm. Average temperatures on the plains exhibit mild variations, with warm summers (December to February) featuring highs ranging from 18°C to 22°C and cooler winters (June to August) with highs between 9°C and 12°C. Frosts can be expected during the winter months. Rainfall is distributed moderately throughout the year, with the wettest period occurring from April to August. Annual rainfall totals vary between 700mm and 1,000mm, albeit with slight regional differences. Sunshine is a notable feature, with 4 to 7 hours of sunshine per day on average. Prevailing westerly winds in the region are generally moderate in speed. Furthermore, the climate on the Waimea Plains is influenced by natural climate variability, such as El Niño and La Niña events, which can lead to periods of drought or increased rainfall.

Looking ahead, the long-term climate forecast for the Waimea Plains suggests some notable trends. Temperature-wise, there is a projection of slightly warmer conditions, with an increased likelihood of hot summer days attributed to global climate change. Winters are expected to maintain their relative coolness. In terms of precipitation, while annual rainfall totals may not undergo significant alterations, climate models indicate potential shifts in rainfall patterns. More intense rainfall events could occur, raising the risk of flooding, particularly during the wetter months. Additionally, the region may experience more extreme weather events, such as heatwaves and heavy rainfall.

Geology

Geological survey assigns the majority of the property as Middle Pleistocene river deposits. The main rock type is gravel, which is described as “weathered greywacke gravel overlain by loess” by the regional geological survey (Q-Map V3). The age estimate of 250,000 years old, provided by geological survey is considered a minimum. The observation of deeply weathered regolith, rotted gravels, the accumulation of residual quartz, and the presence of Ultic soils suggests that the alluvial fan that the property occurs within, is one of the oldest surfaces in Southland, i.e., as old as 430,000 to 450,000 years. This would suggest that the alluvial fan predates the Last Glacial Maximum (26,500 to 19,000 years ago), and that Waimea Glaciation, approximately 330,000 to 340,000 years ago. The smallest geological unit, more recent Holocene river deposits, occurs in the north-eastern corner of the property and is described as “unconsolidated gravel, sand and peat in modern stream beds”. The maximum age estimate of this landform is 14,000 years old.

Soils

The incumbent TopoClimate South soil survey identifies five main soil series across the property, represented by two soil orders – Brown and Pallic (Figure 5).

The Brown soils are Crookston, with an extent of 167.6ha (52 percent of the property) through the heart of the property, Kaweku with an extent of 34.9ha (11 percent of the property) forming a wedge shape starting along the northern boundary, and Crookston + Dipton with an extent of 35ha (11 percent of the property) forming a wedge shape along the southern boundary. Brown soils are the most versatile of the soil orders with few limitations for pastoral farming. The Crookston soil is described as moderately deep, well drained silt with moderate over slow permeability. The Kaweku soil is described as shallow, moderately well drained, clay with moderate permeability (4–72mm/hr). The Crookston + Dipton soil is described as 60% moderately deep, well drained silt and 40% shallow, poorly drained, silt. This combined soil has a moderate over slow permeability.

There are three Pallic soils identified on the property. Generally, Pallic soils have pale coloured subsoils, weak structure and high density in the subsoils. They can be limited by summer dryness and winter wetness. The Pallic soils are Dipton + Kaweku with an extent of 59.1ha (18 percent of the property) along the eastern part of the property; Dipton + Makarewa with an extent of 21ha (6.5 percent of the property) situated along the eastern boundary; and a small area of Dipton with an extent of 5ha (1.5ha). Generally, Pallic soils have pale coloured subsoils, weak structure and high density in the subsoils. They can be limited by summer dryness and winter wetness.

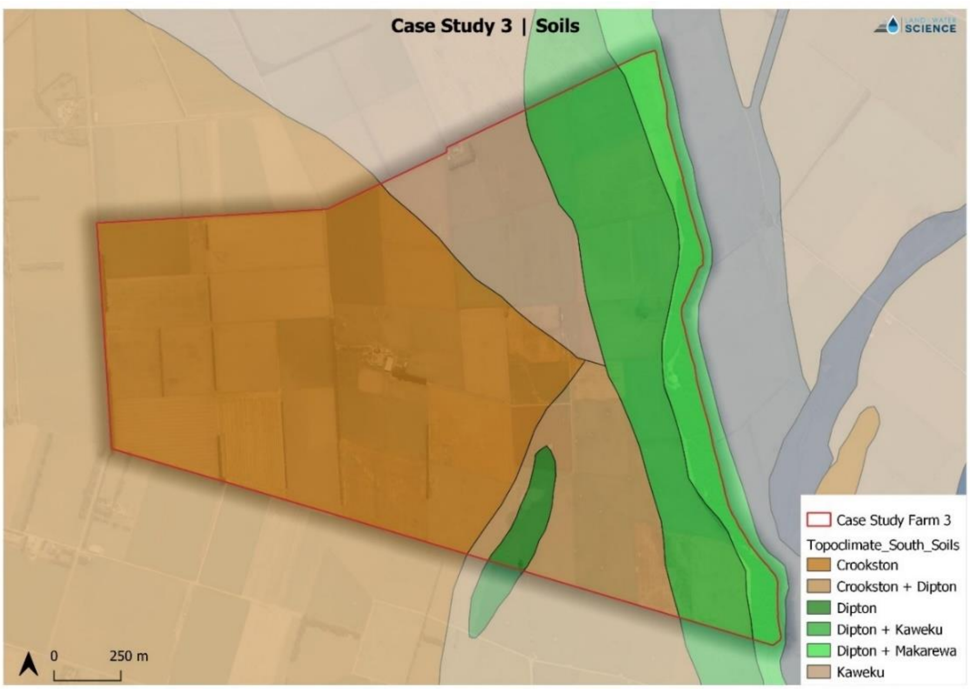

Figure 5 Topoclimate south soil series mapped at 1:50,000 scale.

However, as part of a separate project for the local Catchment Group, a high-resolution radiometric survey was undertaken across the Balfour Fan (~1,400ha) to generate a data-driven digital soil and geological map. The new map, in conjunction with the excavation of soil pits to the groundwater table in places, has enabled greater insights into the soils and geology of the fan.

The radiometrically derived soil and geological map, along with ground-truthing, suggests the soils of the Balfour Fan to be more complex than what has been previously mapped. The higher resolution, more refined analysis indicates the soils covering most of the property are more likely to be “Benio” soil. The

Benio soil is classified as an Ultic soil, according to the New Zealand Soil Classification system. Ultic soils make up <2% of the soils in Southland region on an area basis. They represent the oldest and most weathered soils in Southland. Due to their age, Ultic soils have experienced more leaching and weathering than other soils within the region. Consequently, they often exhibit nutrient deficiencies, particularly in nitrogen and phosphorus. The soil pH typically ranges from acidic to slightly acidic. Due to the abundance of the oxides and oxyhydroxides of iron and aluminum, Benio soils have strong anion exchange, which results in the retention of P and the accumulation of sulphate within subsoils.

The Benio soils across the majority of the property are well, to excessively well drained, due to a high content of quartz sands, that are coated with clay. Due to their drainage characteristics and extreme weathering, the soils and aquifer materials of the Balfour fan are less able to remove nitrate than younger soils and aquifer materials. As such, Benio soils are defined as having a 'severe' susceptibility to nitrate leaching loss. As the soils transition from the western central portion of the property, the fine silt and clay content of the soils increase and internal drainage transitions to moderately to imperfectly drained. With the increase in fines and a decrease in internal drainage, leaching of nitrate to the underlying aquifer decreases. Across the same gradient, the water table shallows and groundwater flows towards the margins of the property, discharging at shallow levels as seeps and springs, most of which have been artificially drained and piped to the Longridge Stream.

Based on the new data-driven soil map (Figure 6) the following was identified:

- The oldest surface which is described as well-drained and has a very high nitrate susceptibility, covers 95.2ha (29% of the property).
- Transitioning across the property from west to east, the next oldest surface is described as moderately well-drained, has a high nitrate susceptibility, and covers 50.7ha (16% of the property).
- Following that, the next soil class is described as imperfect over well-drained, has a moderately high nitrate susceptibility, and covers 64.8ha (20% of the property).
- The next soil classes described as imperfect over moderately well-drained and with a moderate nitrate susceptibility is reflective of the Crookston soils, and covers 37.3ha (12% of the property).
- Transitioning up into the north-east area of the property, the next soil classes are described as imperfect to poor over well/moderately well-drained with a moderately low nitrate susceptibility and covers 24ha (7% of the property).
- The next soil class is described as imperfect to poor over moderately well-drained, with low nitrate susceptibility and covers 26.5ha (8% of the property).
- Lastly, in the north-east corner, the last soil class described as having poor to imperfect drainage with very low nitrate susceptibility covers 23.8ha (7% of the property).

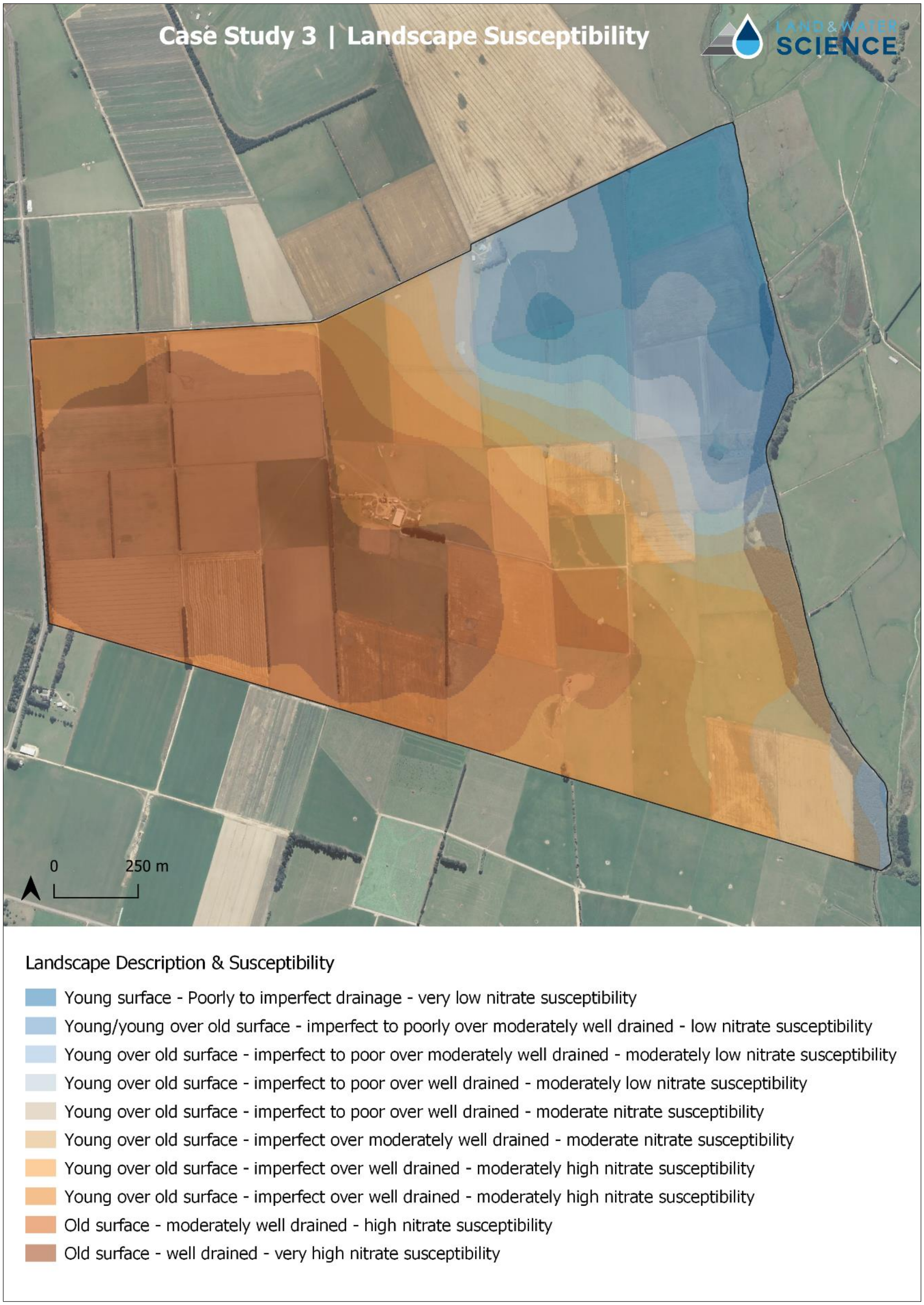

Figure 6 Radiometrically derived high-resolution data-driven soil map.

4.2 The farm – arable, sheep, dairy grazing and lease

Farm system description

The 321ha farm (295ha effective area) is predominately used for mixed arable cropping (205ha) with the balance utilised for livestock grazing – a mix of wiltshire ewes, hogget grazing and dairy heifer grazing.

Farm summary (2022/23 season)

Total area	321ha
Effective area	295ha
<u>Land use</u>	
Productive – mixed cropping	221ha
Productive – livestock grazing	74ha
<u>Stock</u>	
Dairy grazing (yearlings)	105
Breeding ewes	150
Lambing %	140
Hogget grazing	700
<u>Fertiliser, crops and pasture</u>	
Synthetic nitrogen (on average)	123kg N/ ha/ yr
To pasture	0kg N/ ha/ yr
To crops	0-296kg N/ ha /yr
Phosphate fertiliser (on average)	19kg P/ ha/ yr
To pasture	0-41kg P/ ha/ yr
To crops	0-50kg P/ ha/ yr
Supplements sold (crop residues)	68t DM
Supplements imported	0t DM
Crops grown (some paddocks had multiple crops)	
Wheat (winter)	90.0ha
Barley (spring)	24.5ha
Barley (winter)	19.2ha
Tulips (lease)	21.7ha
Oil seed rape	26.8ha
Peas	5.2ha
Lucerne	5.3ha
Oats	5.2ha
Winter crop (for livestock grazing)	
Winter 2022	31.4ha
Winter 2023	19.8ha
Pasture grown	74.4ha
Pasture yield (estimated by OverseerFM)	9t DM / ha / yr

Crops

The farm has a range of soils, with the western side and middle of the property being more suitable for cropping. This area comprises 56% of the property.

The crop rotation is always evolving, but for the 2023/24 season the crop rotation for the main cropping area (56%) of the farm is as follows:

Table 3 Case study crop rotation for main cropping area

Crop	Plant	Harvest
1. Tulips	April	February
2. Winter wheat	April	February
3. Winter wheat	April	February
4. Autumn barley	April	January
5. Kale/swedes	Feb	June to August/September
6. Spring barley	Oct	March
7. Peas	Oct	February
8. Winter wheat	April	February

The above crop rotation is simplified – other crops such as oil seed rape, oats and lucerne are also included in the rotation. Crop rotation decisions are made based on market prices, targeting feeds for human (rather than animal) consumption, weeds and soil conditions. Sheep graze on stubble and cereal regrowth.

The eastern side of the property (44% of the property) has wetter soils, less suitable for cropping. It has a mixed land use of livestock grazing and cropping activities, and has no fixed cropping rotation.

During the 2022-23 season the following areas were grown/harvested (some paddocks had more than one crop in a single season):

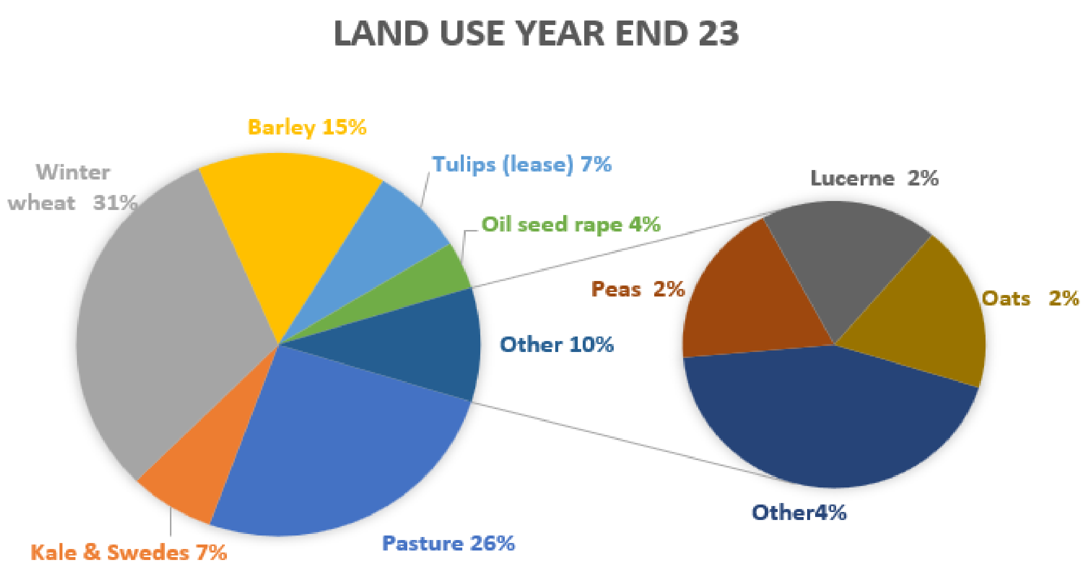

Figure 7 Land use by percentage for year end 2023.

The amount of income from each land use in the 2022/23 season:

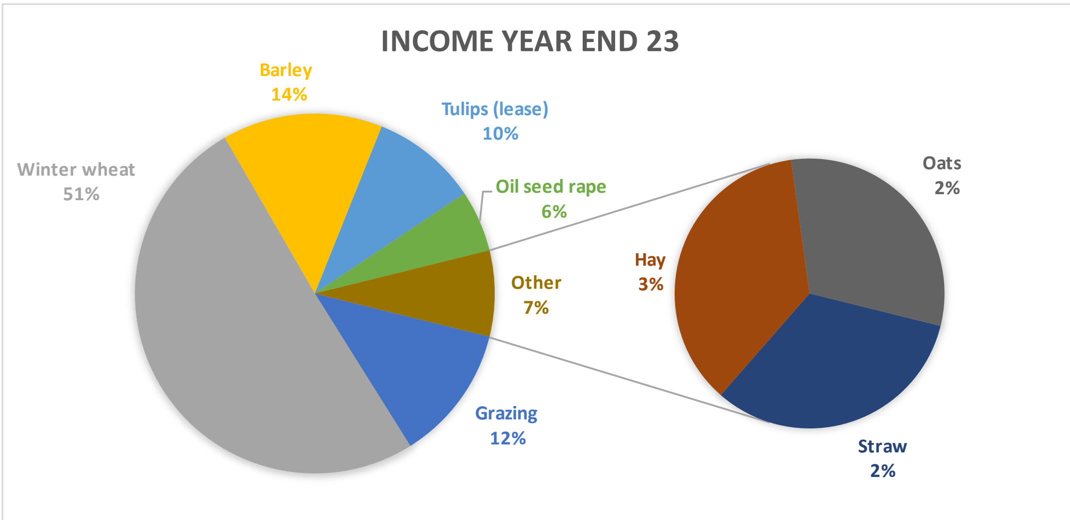

Figure 8 Income by percentage for year end 2023.

Note

Payment schedule for crops is dependent on contract and, in some cases, income is not received in the year of harvest.

Income was also received for rebates and is not shown above (<1%).

Farm nutrients and greenhouse gas emissions

Estimates of nutrients and greenhouse gas emissions have been modelled using OverseerFM (Table 2).

"OverseerFM provides a way to estimate how nutrients are cycled within a farm system. This allows the user to better understand annual average nutrient requirements and the likely effects of changing management practices on the farm's overall nutrient inputs and losses."[3]

OverseerFM models nutrient flows to the farm boundary. The farm boundary is to the farm gate and to rooting depth. It does not model what happens to those nutrients beyond this boundary, nor does it model extreme weather or events.

OverseerFM greenhouse gas estimates have been calculated using IPCC global warming potentials. Estimated change in total greenhouse gas emissions (methane, nitrous oxide and carbon dioxide combined) are reported. In addition, the estimated change in nitrous oxide emissions is identified to align with the specific opportunities identified in the landscape susceptibility mapping.

Modelling biological systems is not exact and there are uncertainties – results are intended to give a 'direction of travel' rather than accuracy.

Table 4 estimates of nutrient and greenhouse gas emissions

Case Study 3 – 2022/23 season OverseerFM v6.5.4	
Total farm emissions (eCO2 t/ yr)	964 33% nitrous oxide 32% methane 35% CO2
Emissions per hectare (eCO2 kg/ ha/ yr)	3003
Total farm N loss (kg N/ yr)	7383
N loss/ha (kg N/ ha/ yr)	23
Surplus (kg N/ ha/ yr)	49
Total farm P loss (kg)	35
P loss/ha (kg P/ ha/ yr)	0.1

[3] https://www.overseer.org.nz/our-science

5 Environmental contaminants

5.1 Environmental contaminants

Greenhouse gases

Rising concentrations of greenhouse gases in the atmosphere increase the earth's temperature. Greenhouse gases comprise of long-lived (carbon dioxide and nitrous oxide) and short-lived gases (methane).

The New Zealand Government has the following legislated emissions targets:

- reduce methane (CH4) emissions by 10% below 2017 levels by 2030, and by 24-47% by 2050
- achieve net-zero emissions for both nitrous oxide (N2O) and carbon dioxide (CO2) by 2050.

Both methane and nitrous oxide are very potent greenhouse gases. Methane warming potential is circa 30 times more powerful than carbon dioxide. The predominate source of methane in New Zealand farming systems is from ruminant digestive systems. N2O warming potential is circa 300 times more powerful than CO2.

In New Zealand, most nitrous oxide is produced by microorganisms acting on nitrogen introduced to the soil via livestock urine or synthetic fertilisers.

Nitrate

Nitrate is highly soluble and is easily transported through the soil if not used by plants and microorganisms. Nitrates can be transported to ground and surface waters, where it may cause human health and ecological issues. Nitrogen is an essential element for plant growth and is generally added to pastures through biological fixation (in clovers), as fertiliser (in synthetic and organic forms), as effluent or urine from livestock.

Organic and ammoniacal nitrogen (TKN)

Total Kjeldahl Nitrogen (TKN) is a measure of organic and ammoniacal nitrogen. Organic and ammoniacal N are derived from the breakdown of organic matter (plant roots, leaves), soil organic matter, manure and animal urine. Organic N is mineralised to ammoniacal N, and ammoniacal N is oxidised to nitrite and ultimately nitrate. The loss of excessive TKN from land, e.g. from a recently cultivated paddock, is therefore an important factor controlling stream health.

Particulate phosphorus

Phosphorus is a nutrient for plants and algae. High concentrations in waterways can cause weed growth and algal blooms. Sources of phosphorus are weathering of rocks, erosion of soil and the addition of phosphate fertilisers to pastures and dung from livestock.

Particulate phosphorus (PP) refers to phosphorus that is associated with particles such as suspended sediments. Phosphorus binds to soil particles. When soil is lost by runoff it takes the phosphorus with it.

Particulate phosphorus loss requires water to erode and carry sediment that is enriched in phosphorus to a waterway. The risk of runoff is elevated with an increasing slope of land. Soils with elevated P-retention can sequester a large amount of P from fertiliser or animal wastes. Erosion of such soil can transport large amounts of P to waterways where it drives eutrophication. Soils that are imperfectly to poorly-drained tend to be more susceptible to P loss via runoff or mole-pipe drainage. Well-drained soils tend to have a low susceptibility to PP loss as they are less likely to runoff. However, well-drained soils with elevated Olsen P values can release higher concentrations of dissolved P into soil solution. Ensuring

Olsen P values do not exceed optimal values is a good way of limiting dissolved P leaching.

Dissolved reactive phosphorus

Dissolved reactive phosphorus (DRP) refers to the soluble phosphorus compounds in water and is the dissolved P fraction that is not attached to sediment. The redox (reduction-oxidation) environment determines the mobility of DRP in the soil and groundwater systems, and the abundance of P. Soils and groundwater systems that are low in oxygen (anoxic) tend to leach dissolved reactive phosphorus. Poorly-drained soils lose more DRP than well-drained soils due to lesser P-retention. Under low oxygen conditions (anoxic), the minerals that hold onto P (P-retention) dissolve, releasing P. Alternatively, if P is introduced to such an environment, it may not be retained by the soil or aquifer materials.

Sediment

Sediment is the loose sand, silt, clay, and other organic particles suspended in a waterway or settled on the bottom. Sediment can come from soil erosion or the decay (decomposition) of biological material and is transported by water, wind and ice to waterways. Although sediment is a natural part of a waterway, the type and amount potentially available to transport is influenced strongly by the geology and topography of the surrounding area and land use practices. Weaker or fine textured rock types, such as mudstone, naturally have a higher sediment load and more turbid water due to these rock types being more easily erodible. This natural sediment load is elevated by land use practices that cause structural damage to soils or leave soil bare and exposed. Under agriculture, sediment can also be enriched with nutrients. Nutrient-rich sediment has a much larger detrimental effect in waterways than sediment from natural state or areas with a low land use intensity.

E. coli

Microbial contaminants are disease-causing organisms. E. coli (Escherichia coli) is just one type of bacteria commonly found in the gut of warm-blooded animals and people. High concentrations of E. coli indicate contamination, which can degrade drinking water supplies and the safety of waterways. Microbes and bacteria often 'stick' to particles (sediment) and are then transported to waterways in runoff, particularly after heavy weather.

For more information on environmental contaminants, see landscapedna.org/science/water-quality-contaminants/

State of the Mataura Catchment

Land use and various industrial and municipal water discharges are key contributors to the degradation of water quality in the Mataura Catchment[6].

Currently, the Toetoes Estuary, where the Mataura River discharges at Fortrose, is considered to be in poor condition. Toetoes Estuary has areas currently assessed as D band (poor) for macroalgae, Gross Eutrophic Zone (GEZ), mud content and sediment oxygen levels. A reduction in nutrient and sediment inputs is needed to improve the estuary classification above 'D' band (poor). Faecal bacteria also needs to be reduced to at least C band (fair) or better at the estuary monitoring sites.

Overall, surface water quality in the Mataura Catchment is characterised by elevated E. coli (faecal bacteria), nitrogen, phosphorus, and degraded macroinvertebrate community index (MCI).

The Waimea Plains Ground Water Management Zone (GMZ) has high nitrate levels near Balfour. Elevated nitrate concentrations in this area reflect a combination of the limited denitrification potential of overlying soils, combined with the slow rate of groundwater throughflow and lack of low nutrient recharge input from surface water.

For further information on water quality in the Mataura Catchment, refer to Appendix 1.

6 Landscape susceptibility

Variability in climate, topography, geology and soils significantly influence the type of contaminant and severity of water quality outcomes, even when land use is the same. We refer to the variability in climate, topography, geology and soil as 'landscape factors'. These are the physical, chemical and biological (organic matter) components of the earth that control the susceptibility ('risk') of the landscape to contaminant loss (Figure 9).

Landscape factors, especially soil texture and drainage also have a significant effect on governing soil greenhouse gas (GHG) production. For geologically diverse landscapes, such as New Zealand, the type and severity of contaminant loss varies significantly. Even in relatively simple landscape settings, variation in landscape factors may account for the majority of spatial variation in water quality relative to land use on its own.

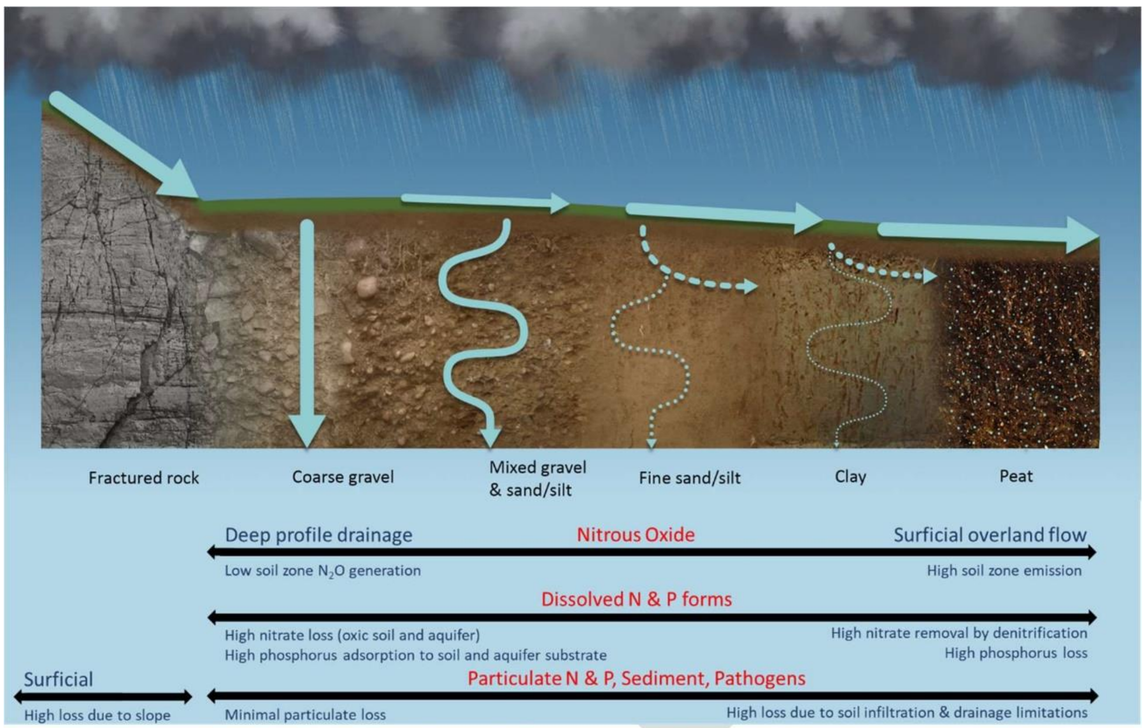

Figure 9 Conceptual diagram of susceptibility for contaminant loss under various landscape properties. Susceptibility for contaminant loss is strongly controlled by the pathway water takes to leave the land and the chemical processes of reduction-oxidation.

LWS has generated a classification that maps the landscape factors controlling variation in the type and severity of water quality issues. The Physiographic Environments of New Zealand classification (www.LandscapeDNA.org) is designed to support land users in understanding how and why water quality variation occurs across the landscape and identify the most important susceptibility on their property.

In doing so, LandscapeDNA supports targeting actions specific to their location and the issues faced. This mapping is undertaken by combining existing soil, geological, topography and climate data to understand the landscape factors controlling variation in water quality. The map has a resolution of 1:50,000. At this scale, it is appropriate for providing catchment context and describing the general farm environment, but is not at a resolution suitable for paddock scale management decision-making.

Mataura River Catchment's physiographic setting is provided in Figure 10. Alpine and bedrock environments comprise 53% of the catchment, with the lowlands dominated by the reducing soil oxidising aquifer (18.2% of the catchment) and oxidising soil and aquifer environment (16.1% of the catchment). For specific details on each physiographic environment and its landscape susceptibility, see landscapedna.org/science/physiographic-environments/.

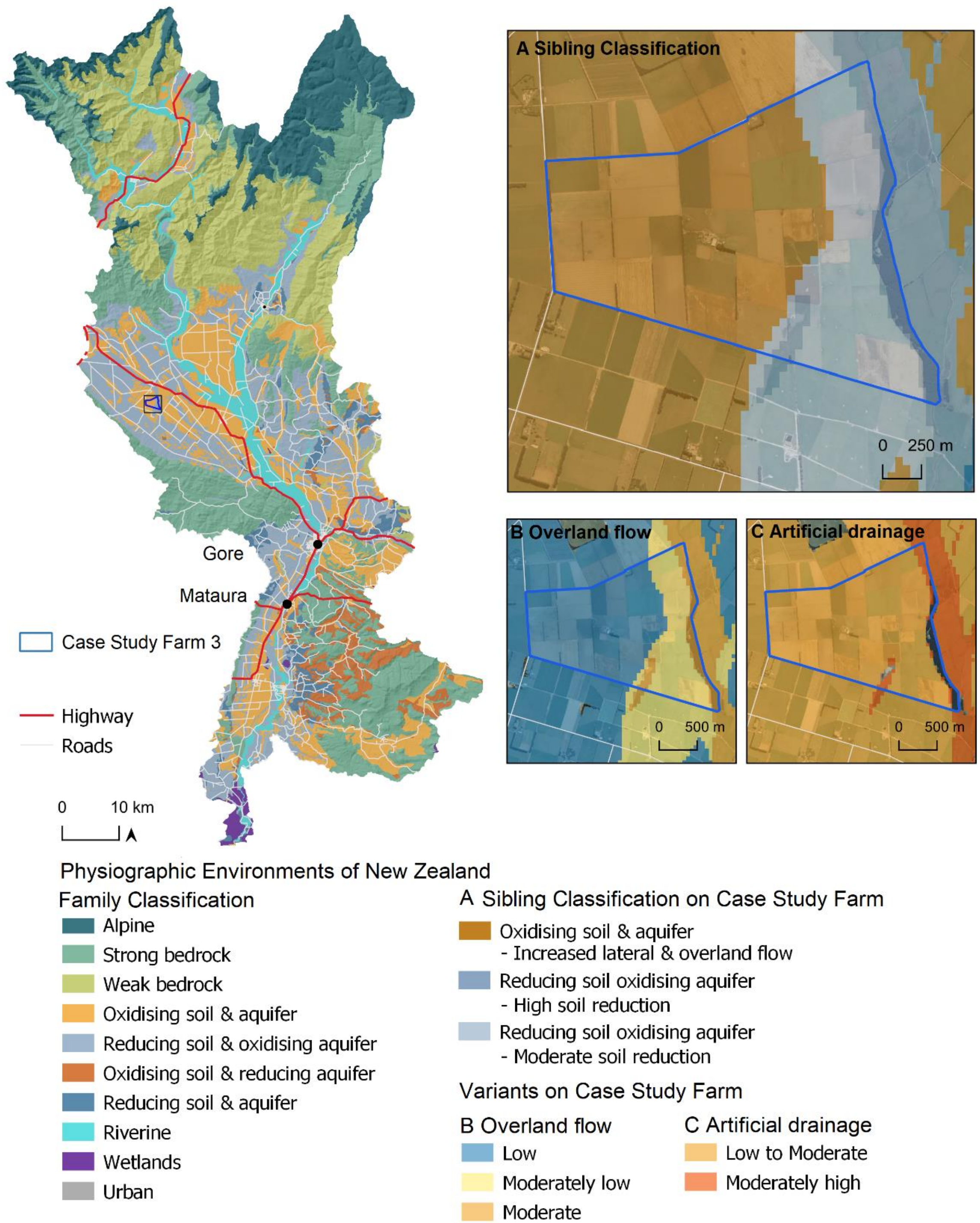

Figure 10 Physiographic environments of the Mataura Catchment and the case study farm.

The case study farm is located predominantly within the oxidising soil and aquifer environment (202ha, 63% of the property; Figure 10a).

Deep drainage to the underlying aquifer is the dominant hydrological pathway, with some lateral flow (as indicated by the sibling classification of increased lateral and overland flow). This environment has a high ability to filter and adsorb contaminants and resist erosion (minimal sediment, particulate P and microbial losses).

As the landscape has little to no ability to remove nitrogen once it has been lost from the root zone, there is a high risk of nitrate-nitrogen leaching into the shallow aquifer. Over time, nitrate can build up in the aquifer, increasing the concentration in groundwater and in-stream. Elevated nitrate concentration is evident in wells drawing from the Balfour aquifer, commonly exceeding the World Health Organisation (WHO) drinking water standards of 11.3 mg/L NO_3-N.

The balance of the property is located within the reducing soil and oxidising aquifer environment (120ha, 37% of the property; Figure 10). This environment occurs in lowland areas with finely textured silt or clay-rich, imperfect to poorly-drained soils and oxygen-rich (oxidising) underlying aquifers. The soils have diagnostic grey colours and distinctive rust-coloured spots.

The ability of the landscape to filter and adsorb particulate contaminants is largely dependent on how much water can infiltrate the soil. The natural drainage of these soils has typically been modified by artificial drainage to lower the water table and improve soil drainage, reducing the occurrence of overland flow (Figure 10b and c). This allows more particulate contaminants to be filtered by the soil and minimises the occurrence of runoff but creates a pathway for water to transport dissolved (and some particulate) contaminants through. These areas are also likely to have elevated soil nitrous oxide loss.

6.1 Susceptibility of case study farm

LWS has undertaken a new, high-resolution physiographic approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales. The resolution of the mapping is 50x50m, providing a much more resolved understanding of contaminant susceptibility than physiographic environments on their own. The maps are of sufficient resolution to show paddock scale variation in susceptibility.

The maps of landscape susceptibility highlight the various contaminants and their forms using a scale of 0-100 (0 being low and 100 being high susceptibility). The landscape's dominant influence on contaminant production and transport means much more attention needs to be paid to these spatially-driven factors.

It is important to emphasise the following for the susceptibility models presented below. They:

A. Are entirely independent of land use and only identify the natural susceptibility of the landscape to contaminant loss associated within soil, geology and topographic factors (e.g. slope, elevation)

B. Do not consider any existing environmental management practices or physical mitigations already in place (e.g. sediment traps, wetlands)

C. Do not represent actual losses or contaminant loads.

The susceptibility maps are coloured from red to blue, reflecting elevated susceptibility to the contaminant or emission in question (red), to reflecting low susceptibility (blue).

Nitrous oxide and NNN

<table>
<tr><th>Landscape susceptibility – N2O (soil nitrous oxide)</th><th>Landscape susceptibility – NNN (nitrate-nitrite-nitrogen)</th></tr>
<tr><td>

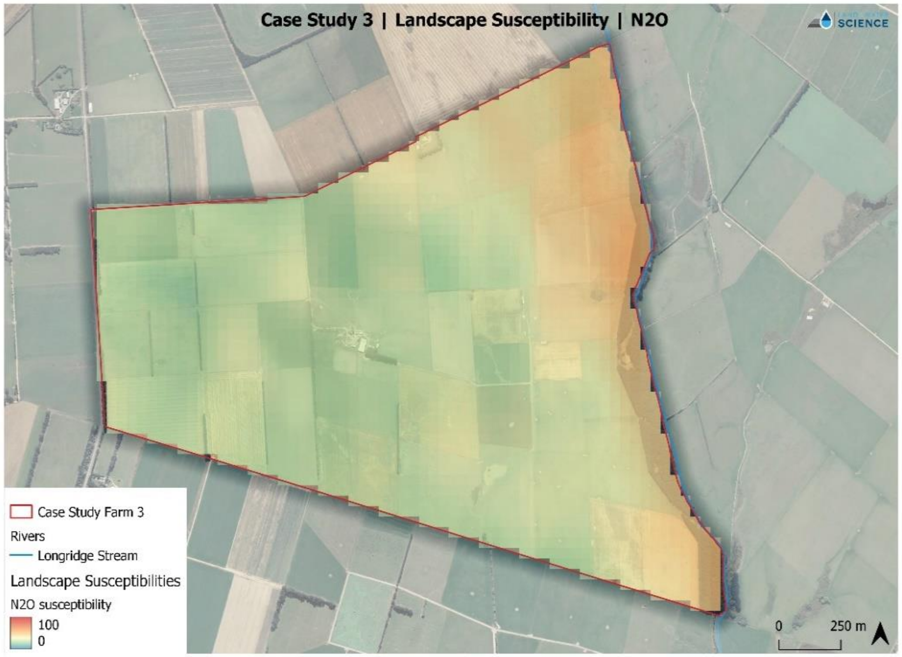

Figure 11 Landscape susceptibility to nitrous oxide.

N2O model indicates low landscape susceptibility across the majority of the property, with moderate susceptibility along the eastern boundary coinciding with soils that are imperfectly to poorly-drained, and known to saturate during the cooler months of the year.

</td><td>

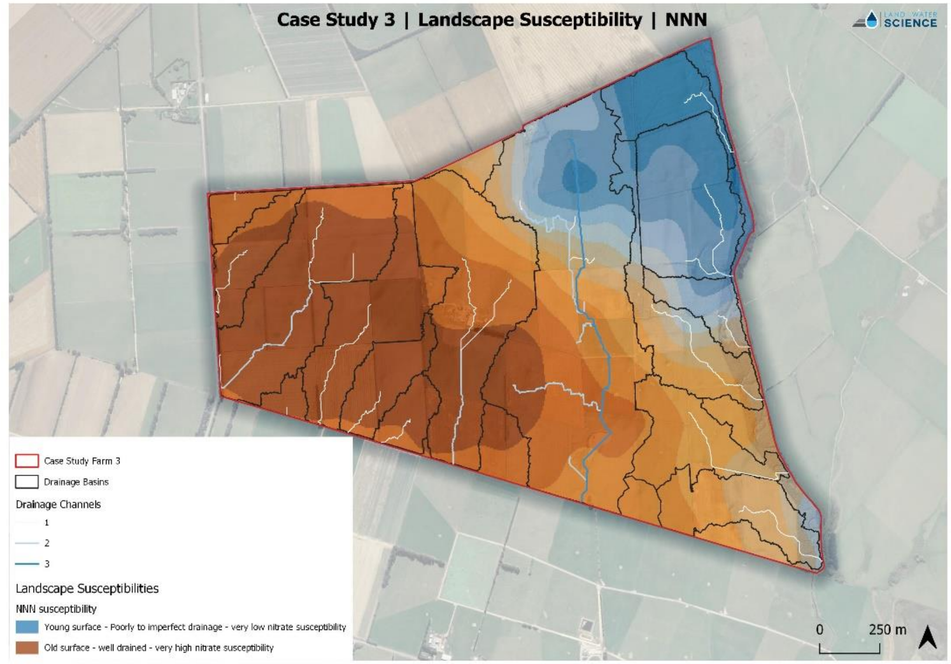

Figure 12 Landscape susceptibility to NNN (Nitrate-Nitrite-Nitrogen).

The highest susceptibility area is located in the western area of the property, coinciding with the oldest and most weathered Benio soil being closest to the surface (reflected by the darkest red shade). The landscape's natural susceptibility to NNN leaching progressively reduces in intensity outwards from the epicentre as the older and more weathered soils are layered beneath younger soils. The lowest NNN susceptibility areas are located in the north-eastern corner, coinciding with soils that are poorly to imperfectly drained.

</td></tr>
</table>

The susceptibility of the landscape to nitrous oxide loss is the opposite to that of NNN leaching (Figures 11 and 12). This reflects the role of redox processes (e.g. oxidation and reduction reactions) in controlling whether or not NNN is removed or able to accumulate.

The main source of nitrogen in Case Study 3 is synthetic nitrogen, with a smaller amount from biological fixation. The nitrogen surplus is 49kg N/ ha/ yr, with an estimate of concentration in drainage of 2-35 ppm of nitrogen leaving the root zone as leachate on the crop areas. On pasture areas the concentration of nitrogen in drainage is estimated at 4-6 ppm.

Particulate phosphorus and dissolved reactive phosphorus

Landscape susceptibility – PP (particulate phosphorus)

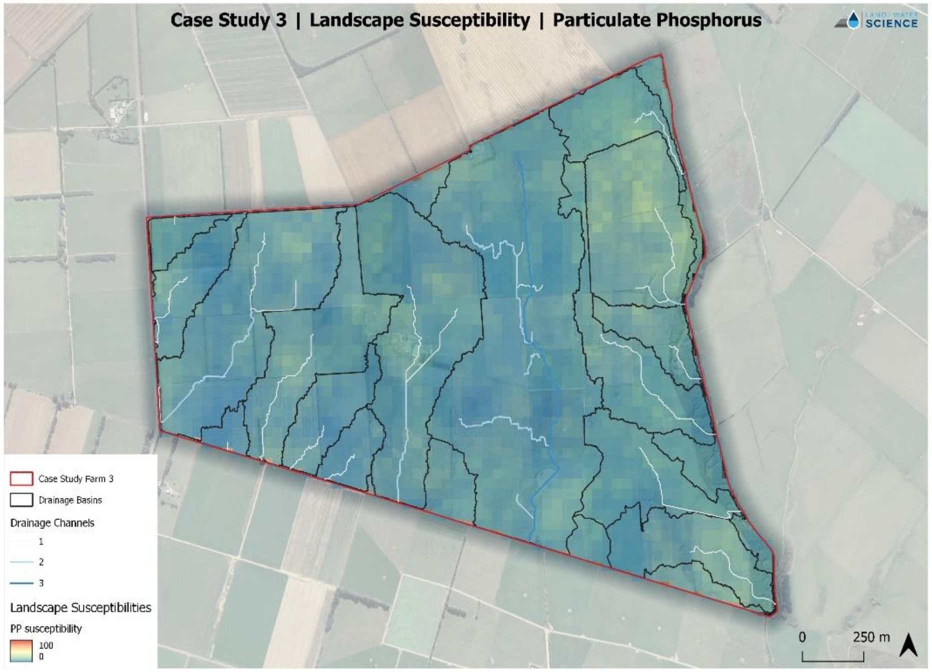

Figure 13 Landscape susceptibility to PP (particulate phosphorus).

The majority of the property's natural landscape susceptibility to particulate phosphorus loss is low. The area in the north-east where the soils are imperfectly to poorly-drained will be more susceptible to overland flow, along with losses of particulates – including phosphorus.

Landscape susceptibility – DRP (dissolved reactive phosphorus)

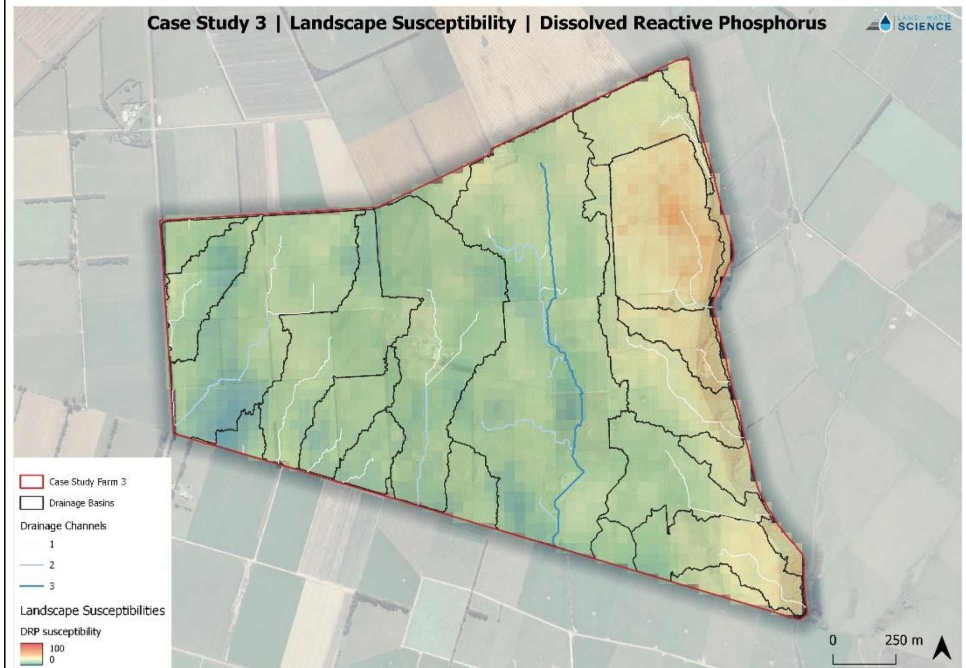

Figure 14 Landscape susceptibility to DRP (dissolved reactive phosphorus).

There is low landscape susceptibility to DRP loss across the majority of the property. An elevated area of landscape susceptibility occurs in the north-eastern area, coinciding with where the soils are imperfectly to poorly-drained.

The topsoil P-retention[4] ranges from low (22% on the Dipton soils) to medium on the Crookston, Kaweku and Makarewa soils (36-43%). Soil tests were taken on crop paddocks at a depth of 0 to150mm in September 2021 and March 2022. The month of testing aligned with the sowing of arable crops.

The average Olsen P value from March 2022 soil test results[5] is 22mg/ l with variation between blocks (range of 15-32mg/ l). For sedimentary soils, Olsen P should be maintained in the 20-30 range for crop rotations (and pasture production)[6].

---

[4] Manaaki Whenua Landcare Research S-Map soil reports
[5] Hill Laboratories report – soil test results, soil sample depth 0-150mm, March 2022 by Ballance Agri-nutrients
[6] Managing soil fertility on cropping farms – Fert Research

Turbidity and organic and ammoniacal nitrogen

Landscape susceptibility – sediment (turbidity)

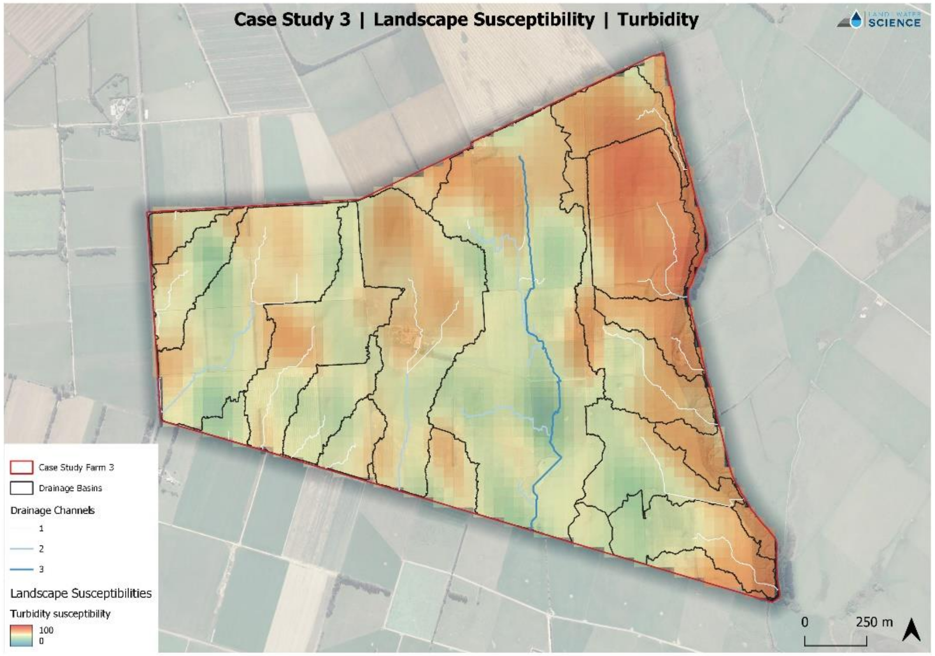

Figure 15 Landscape susceptibility for sediment as indicated by turbidity.

The susceptibility model for the Case Study 3 property indicates the areas of greatest sediment susceptibility occur along the north-eastern boundary. It is important to note that while this area boundaries the Longridge Stream, the majority of the boundary length has already been planted in trees.

Landscape susceptibility – TKN (organic and ammoniacal nitrogen)

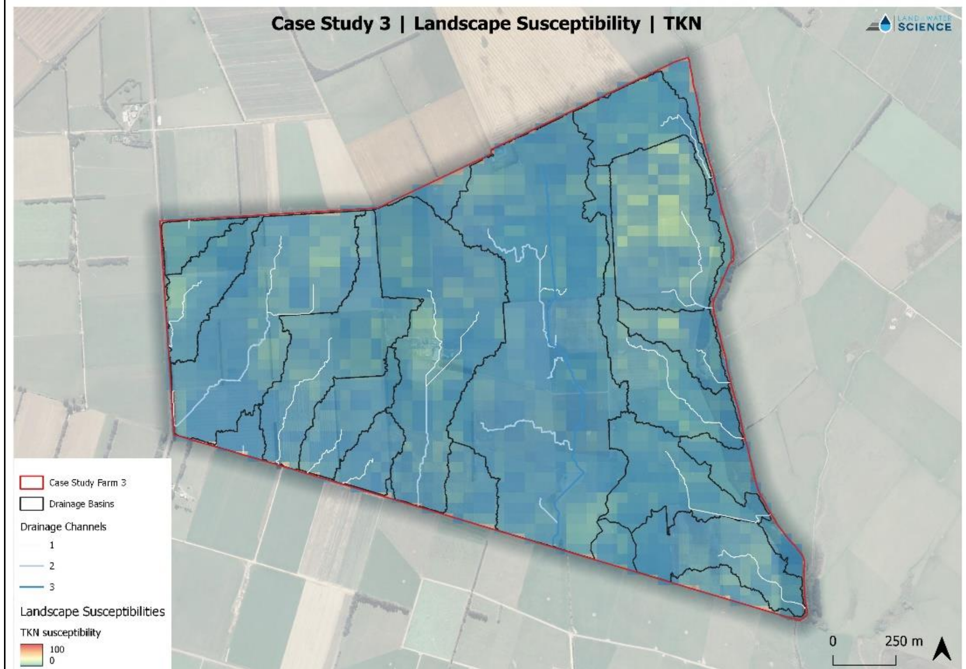

Figure 16 Landscape susceptibility to organic and ammoniacal nitrogen.

The majority of the property's natural landscape susceptibility to organic and ammoniacal nitrogen loss is low. The area in the north-east where the soils are imperfectly to poorly-drained will be more susceptible to overland flow, which is similar to nitrous oxide and PP. The similarities are to be expected as soil saturation plays a critical role over the susceptibility of each of these contaminants to loss.

E. coli

Landscape susceptibility – *E.coli*

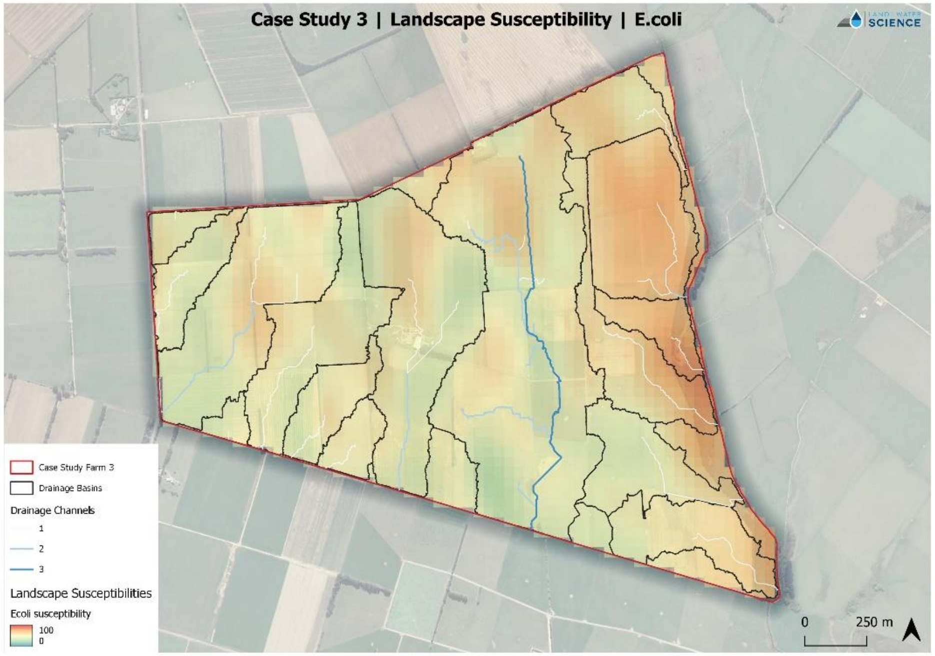

Figure 17 Landscape susceptibility to E. coli (Escherichia coli) contaminants. Microbial contaminants are disease-causing organisms. E. coli (Escherichia coli) is just one type of bacteria commonly found in the gut of warm-blooded animals and people

The highest susceptibility areas for this property are located around the north-eastern corner. However, there is low confidence in the susceptibility model for *E.coli* relative to the other contaminants.

7 Environmental mitigation opportunities

Using landscape susceptibility, the property has been split into four key sectors:

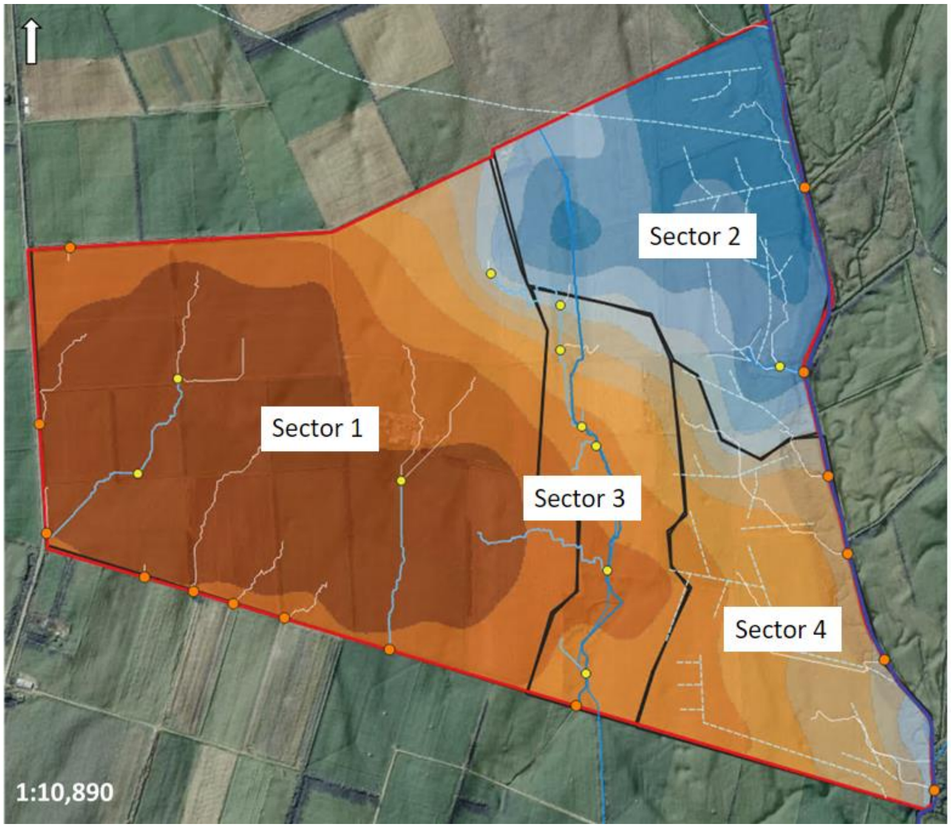

Figure 18 The farm map showing the key susceptibility by sector.

Sector 1:
Extreme nitrate leaching through deeply weathered, well-drained and sandy soils. Nitrate levels exceed 20mg/ L NO3-N beneath these soils. The well-drained soils overlie schist, which forces groundwater flow laterally towards the margins of the fan and the Longridge Stream. Nitrate source reduction is key here.

Sector 2:
Poorly-drained soils, remnant peat wetland, anoxic (stagnant) shallow groundwater adjacent to the Longridge Stream. Particulate and intermediate contaminants (ammoniacal nitrogen, dissolved organic N and P) is the main susceptibility. Runoff prevention and interception is the main focus.

Sector 3:
Ephemeral to intermittent stream that is associated with many small, remnant wetlands. Episodic runoff discharges to the Waimea Stream to the South. Options to consider are the size of wetland and sediment traps. This would also support addressing the runoff from upstream properties.

Sector 4:
Imperfectly drained (well to poor) soils, with significant fall across this sector. Subsurface drainage intercepts young, nitrate rich groundwater and discharges directly to stream via the artificial drainage network. Options are to intercept or block tiles and let this area revert to a groundwater-fed wetland system.

Taking into account landscape susceptibility, farm systems analysis and discussions with the farmers, the opportunities to reduce environmental impact are as follows (Figure 19).

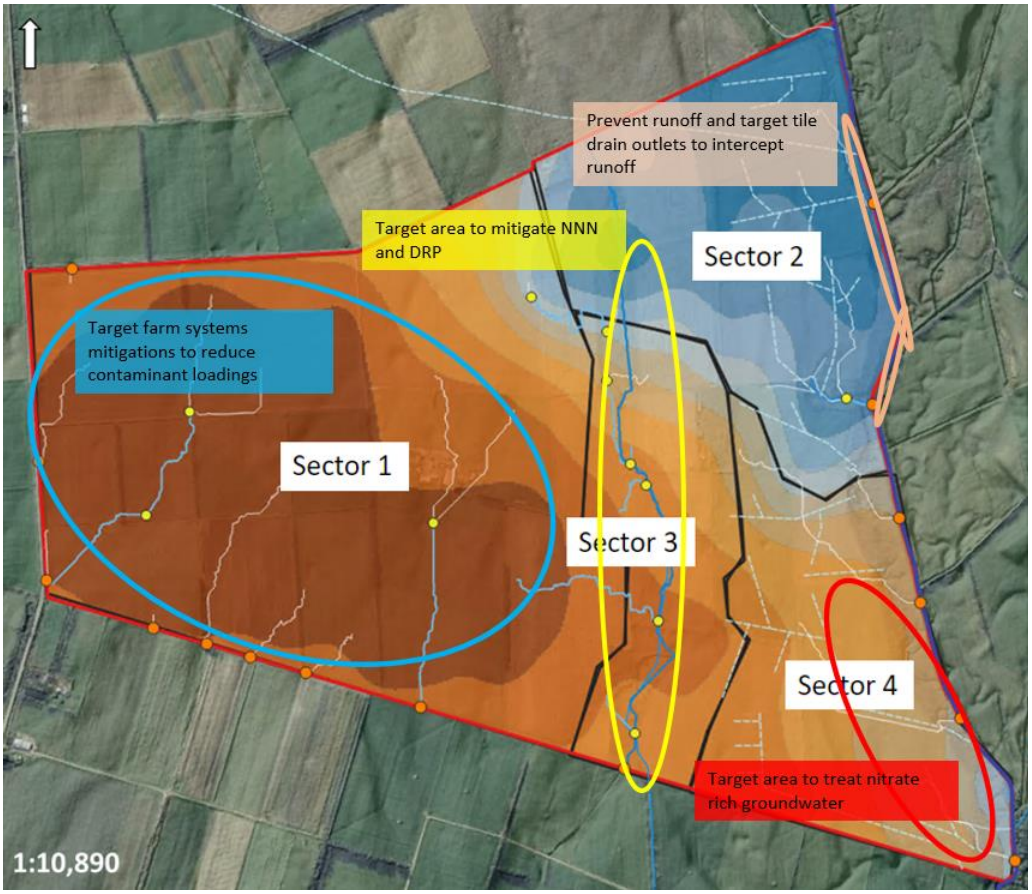

Figure 19 Farm map showing targeted mitigations to key susceptibility by sector.

Opportunities to reduce environmental impact were investigated and modelled through OverseerFM, then compared against the 2022/23 season.

Considering actions that entail high farm system change/cost requires extensive analysis, as these changes impact:

- income
- costs
- capital requirements
- profitability
- stock and pasture/feed management
- skills required to operate changed farm system.

Partial budgeting was utilised to explore the high-level impact of farm system change on capital investment and farm working expenses. This method has been chosen so farmers can follow the approach and relate it to their own situation.

Further analysis should be undertaken before finalising any decisions, using a model such as Farmax to analyse farm system feasibility and detailed budget/cashflow implications.

7.1 Mitigation options – farm system, landscape and land use

7.1.1 Option 1: targeting nutrients applied to plant requirements and uptake

Description

Plant-based good management[7] practices to reduce the risk of nutrient losses are:

- managing nutrient supply from all sources: soil, crop residues and soil organic matter
- regular soil testing to identify nutrient (N and P) needs
- using expert guidelines: crop calculators, codes of practices and expert opinions
- applying fertiliser strategically to meet agronomic requirements
- using nutrient budgets
- side dressing/split application of fertilisers.

'Soil nitrogen (N) testing is important for forecasting how much additional fertiliser N may be needed to meet, but not exceed, the demand of a growing crop.

The N supplied directly by soil can be divided into two forms:

> *<u>Mineral N</u> = the plant-available N in soil at the time of sampling*
>
> *<u>Mineralised N</u> = the N released (mineralised) from soil organic matter during the growing season.'*[8]

Previously the case study farmers had been utilising a limited number of soil tests, along with plant tissue testing for decision-making. Optimising nitrogen use efficiency (for crop production and profitability) has been assumed with the good management practices:

- Using both soil mineral N and potentially mineralizable N from soil testing prior to sowing (soil testing could also identify other deficiencies eg potash and phosphorus)
- Leaf testing for in season fertiliser application
- Fertiliser is applied at the correct plant stage.

The year end 2023 has been remodelled considering good management practices based on rate and timing (and using the assumption of available soil nitrogen of 100[9]kg/ ha).

See Appendix 2 for a list of the recommended good management practices by crop.

---

[7] *Chakwizira E. January 2023. Mitigation options to reduce nutrient loss in the Otago Region. A Plant & Food Research report prepared for: Otago Regional Council.*
[8] *Factsheet: Guidelines for Soil Nitrogen Testing and Predicting Soil Nitrogen Supply. (2022) Plant and Food Research.*
[9] *Based on an average of a limited amount of soil test data available.*

Impact on environmental contaminants

Table 5 Targeting nutrients applied to plant requirements and uptake (excluding land leased to tulips).

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
8% decrease	11% decrease	20% decrease	69% decrease	No change

Compared with the year end 2023.

The predicted environmental impact has been calculated for the case study farmers' crops, and does not include the land leased out for tulip growing. Fertiliser practices are not stipulated in the lease agreement.

Should fertiliser be applied to the tulip crops as outlined in Appendix 2, the change in environmental impact (at a whole farm scale) is outlined in Table 6.

Table 6 Targeting nutrients applied to plant requirements and uptake (including land leased to tulips).

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
11% decrease	15% decrease	22% decrease	90% decrease	No change

Compared with the year end 2023.

Farm system

More time will need to be spent soil and plant testing and using the information to inform decision-making.

Financial impact

An increase in soil and plant testing costs will be offset by a significant reduction in fertiliser expenditure.

Table 7 Partial budget for targeting nutrients applied to plant requirements and uptake (excluding land leased to tulips).

Increase income None	Reduce income None
Reduced costs Fertiliser savings (excluding tulip area) = $26,696	Increased costs Soil testing (soil mineral N), 26 samples @ $70 per sample = $1820
$26,696	$1820

An estimated cost saving to the case study farmer of $24,876.

Note

The financial impact has been calculated for the case study farmers' crops and does not include the costs of soil testing and fertiliser related to the land leased out for tulip growing. This should be discussed during the next lease contract negotiations.

The impact of future agricultural emissions pricing has not been calculated.

7.1.2 Option 2 – review crop rotations to reduce environmental impact

The crop rotation is always evolving, but for the 2023/24 season the crop rotation for the main cropping area of the farm is as follows:

Table 8 Case study crop rotation for main cropping area.

Crop	Plant	Harvest
1. Tulips	April	Feb
2. Winter wheat	April	Feb
3. Winter wheat	April	Feb
4. Autumn barley	April	Jan
5. Kale	Feb	June to Aug/ Sept
6. Spring barley	Oct	March
7. Peas	Oct	Feb
8. Winter wheat	April	Feb

The above crop rotation is simplified, other crops such as oil seed rape, oats and lucerne are also included in the rotation. Crop rotation decisions are made based on market prices, value add opportunities, targeting feeds for human (rather than animal) consumption, weeds and soil conditions. Sheep graze on stubble and cereal regrowth.

Nutrient losses from a crop will depend on crop type and yield, soil type, soil fertility, fertiliser applications (amount and timing), cultivation practices and previous use of the paddock.

Land-based good management[10] practices to reduce the risk of nutrient losses are:

- managing the period of exposed soil between crops to reduce risk of erosion, overland flow and leaching
- re-sowing harvested areas as soon as practical
- using cover crops to reduce nutrient losses, and improve nutrient use and soil organic matter
- retaining native vegetation in gullies and steep slopes to regulate runoff, reduce soil movement and provide filter area prior to water entering streams.

Monitor soil P contents and maintain them at or below the agronomic optimum for the farm:

- undertake regular, ongoing soil testing. Different crops have different agronomic P thresholds
- leave unfertilized zones/ strips besides creeks/ drains/ stormwater flood zones.

[10] Chakwizira E. January 2023. Mitigation options to reduce nutrient loss in the Otago Region. A Plant & Food Research report prepared for: Otago Regional Council.

Opportunities to reduce environmental impact on the case study farm have been identified as:

- reduce the fallow period following spring barley (in year end 2023, this comprised of 10.7ha). It is assumed that a short rotation ryegrass is planted following the harvest of the barley crop in March and instead of planting into swedes the following December, the short rotation ryegrass is utilised the following winter for grass/baleage wintering. 112.5t DM (490 bales of baleage) is harvested off this area and fed out over winter.
- the remaining 9.1ha paddock that is planted into kale in February is planted into a short rotation ryegrass for grass/baleage wintering.

Note

Other options that could have been considered were:

Removal of the tulip lease – this crop has a period of bare soils, however the income earnt from this crop is significant for the business.

Removal of all livestock (from parts of the farm less suitable for cropping) – this would have created a significant increased dependence on selling feed, which can have a variable market from season to season and increase business risk.

Use of plantain in the pasture mix – plantain is a herb, that when included in pastures is shown to reduce environmental impact. Research has shown a reduction in both nitrate leaching and greenhouse gases (specifically nitrous oxide) in pastures containing plantain. Pasture comprises 25% of this property and a significant percentage of plantain would need to be present in the pasture sward to achieve meaningful mitigation at farm scale.

New crops – analysis needs to be completed from growing the crop (suitability of conditions, resources required), to risks and access to a market to selling the product. As an example, the case study farmers are currently exploring buckwheat, which can be grown for use in the health food market because of its unique nutritional composition and gluten-free status.

Deep rooting crops – some crops are deeper rooting with more extensive root systems. For example, winter wheat roots can reach 24.4km per m^2 of soil in the top 20cm of soil[11]. This compares with spring barley of 8.4km per m^2 in the top 20cm of soil. Increased use of plants with more extensive rooting systems could reduce nitrate leaching.

The above options may need to be reviewed in the future as value-add crops are considered and environmental regulation is required to be met.

Impact on environmental contaminants

Table 9 Remove fallow period on 10.7ha and remove winter fodder crops.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
3% increase	2% decrease	6% decrease	29% decrease	3% decrease

Compared with the year end 2022/23.

[11] https://www.pda.org.uk/crop-root-systems-explain-need-to-maintain-k-index-level/

The overall rise in greenhouse gases is through an increase in carbon dioxide and methane production. Both these surges relate to the increased feeding of supplement (compared to winter fodder crop):

- carbon dioxide produced in the making of supplement
- methane from increase in amount of feed eaten due to a lower quality feed being offered (OverseerFM assumes kale at 12[12] MJ ME per kilogram of dry matter and baleage at 10[13] MJ ME per kilogram of dry matter).

Farm system

If there is low growth in the summer/autumn (e.g. drought) there is a less assured supply of feed from pasture growth than a winter swede crop that has been established pre-Christmas.

The farm would need to build suitable pasture covers through autumn to ensure quality and quantity of feed through winter.

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on farm working expenses. This method has been chosen so farmers can follow the approach and relate it to their own situation. Before finalising decisions, further analysis should be undertaken using a model such as Farmax. This will ensure analysis of farm system feasibility and provide detailed budget/cashflow implications.

Table 10 Partial budget for removing fallow period on 10.7 ha and removing winter fodder crops.

<u>Increase income</u> None	<u>Reduce income</u> None
<u>Reduced costs</u> Costs associated with establishing winter crop – cultivation, seed, spray, fertiliser: 19.8ha at $1800/ ha = $35,640	<u>Increased costs</u> Costs associated with establishment of short rotation – sowing (direct drilling) and seed: 19.8ha at $250/ ha = $4,950 Fertiliser required for short rotation = $10,650 Make an extra 490 bales of baleage at $45/ bale = $22,050
$35,640	$37,650

12 OVERSEER® Technical Manual Technical Manual for the description of the OVERSEER® Nutrient Budgets engine. Characteristics of crops June 2018 Prepared by D M Wheeler AgResearch Ltd
13 OVERSEER® Technical Manual Technical Manual for the description of the OVERSEER® Nutrient Budgets engine. Supplements June 2018 Prepared by D M Wheeler & N Watkins AgResearch Ltd

Overall, there is an increase of $2010 in costs by removing the fallow period, winter fodder crops and grass wintering.

Other impacts

The following has not been calculated:

- the impact on future agricultural emissions pricing.

7.1.3 Option 3 – Managing crop residues

Description

Crop residues have a value in the farm system, e.g. by returning nutrients to the soil following their decomposition or by providing feed for livestock. Residue management practices need careful consideration based on:

- establishment of following crop
- weed and pest management
- soil quality
- timelines of operations
- value of nutrients in residues
- value of sale of removed residues.

The different and most commonly used options for crop residue management are:

- Retaining:
  - incorporating the residue via chopping and non-inversion cultivation (surface/top work)
  - incorporating the residue via chopping and ploughing (full-inversion cultivation)
  - retaining the crop residue on the soil surface and direct drilling through it.

- Stubble burning

- Removing:
  - baling and removing cut straw (may be followed by direct drilling or various cultivation methods).

Table 11 Summary of advantages and disadvantages of different techniques for managing crop residue.

Residue management	Advantages	Disadvantages
Retaining	Nutrients slowly released.	Can affect the availability of soil nitrogen, as the residue decomposes and takes N from the soil. May need to use more chemicals (e.g. slug bait).
Burning	Most potash, phosphorus, calcium and magnesium retained in the ash.	Loss of nitrogen, sulphur and carbon as gas. Nuisance value from the smoke when burning.

Residue management	Advantages	Disadvantages
Removal	Maximizing soil and seedbed quality. Supports sustainable weed management. Reduces pest and disease problems. Minimises cultivation intensity. Income stream from straw sales.	Loss of nutrients (N, P, K, S & Mg). Reduced soil organic matter (SOM) and impact on soil structure if no pasture phase is included in crop rotation[14]. Can delay establishment of next crop. Can result in soil damage/ compaction from extra vehicle movements. Fluctuations in market prices for straw.

Note
When removing and selling crop residue, nutrients are being removed from the farm. For wheat, this would amount to $60-$120/ ha[15].

In the year end 2023, arable crop residues on the case study farm were distributed as follows:

- 115.6ha (66.5%) is retained
- 43ha (24.7%) is burnt
- 15.2ha (8.8%) is removed/sold.

Since the year end 2023 season, the case study farmers have further reduced the area of stubble burnt. They have purchased a new combine harvester which is able to chop and incorporate residue. Chopped residue requires more slug bait. An example was modelled where an extra 41.6ha of winter wheat residue which is currently retained, is sold. Nutrients that were removed were replaced with fertiliser.

Impact on environmental contaminants

Table 12 Removing 41.6ha of winter wheat residue (rather than retaining).

Total GHG change	Nitrous oxide change	N loss change	N Surplus change	P loss change
1.4% increase	2% decrease	1% increase	5% increase	No change

Compared with the year end 2022/23

[14] FAR, 1996 (No. 1)

- [15] Baling and removing 1 tonne of wheat residue per hectare would remove around 6kg nitrogen (FAR, 2013 (Issue 103)); and at the current fertiliser prices (Ravensdown, Dec 2023) this would be about $12 per tonne of residue removed. Typical residues for autumn sown wheat is 5-10t/ ha; resulting in a loss of N equivalent to $60-120/ ha.

Farm system

Timing is critical as it could delay planting of the following crop. The farm would need to increase focus on including pasture in the cropping rotation to preserve soil organic matter/ structure.

Financial impact

Table 13 Partial budget for removing 41.6ha of winter wheat residue (rather than retaining).

Increase income Selling wheat straw – 41.6ha at 7.5t DM/ ha: 312,000kg DM at 15c/ kgDM = $46,800.	Reduce income None.
Reduced costs None.	Increased costs Increased fertiliser at $120/ ha x 41.6ha = $4492. Making straw 312,000kg DM at 8c/ kg DM = $24,960.
$46,800	$29,452

Estimated increase in income of $17,348.

Other impacts

The market for straw sales can be volatile. Extra workload in making straw bales and selling at a busy time of year. The following has not been calculated: the impact on future agricultural emissions pricing.

7.1.4 Option 4 – use of low solubility phosphate fertilisers

Description

Phosphorus loss to waterways can have a significant impact on water quality. The majority of phosphorus loss to waterways is predominantly in the particulate form (attached to soil particles); the remainder of the phosphorus loss to waterways is in soluble phosphorus dissolved in runoff water.

Using a low solubility phosphate fertiliser (such as serpentine super) reduces dissolved phosphorus runoff after a fertiliser application. Super phosphate is highly water soluble (90% solubility), whereas other forms such as serpentine super are less water soluble (15% solubility).

In the year end 2023, 24.8t of triple super was applied to crops and pasture. In this option, the triple super has been replaced with a low solubility product (69.2t of serpentine super).

Impact on environmental contaminants

Table 14 Replacing phosphate fertiliser with low solubility phosphate fertiliser.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
No change	No change	No change	No change	6% decrease

Compared with the year end 2022/23.

Farm system

Inconvenience of handling more product when establishing crops could be an issue.

Financial impact

Table 15 Partial budget for replacing phosphate fertiliser with low solubility phosphate fertilizer.

Increase income None	Reduce income None
Reduced costs	Increased costs Extra fertiliser cost[16] – $4510 Extra transport and spreading cost – $3330
	$7840

No value taken into account for the extra sulphur, magnesium and calcium provided from the serpentine super, as these extra nutrients may not be required.

Other impacts

The following has not been calculated:

- the impact on future agricultural emissions pricing.

[16] *Assumes*
Triple super priced at $1177 per tonne ex store
Serpentine super priced at $487 per tonne ex store
Transport and spreading at $75 per tonne.

7.1.5 Option 5, sector 2 – prevent runoff and target tile drain outlets to intercept runoff

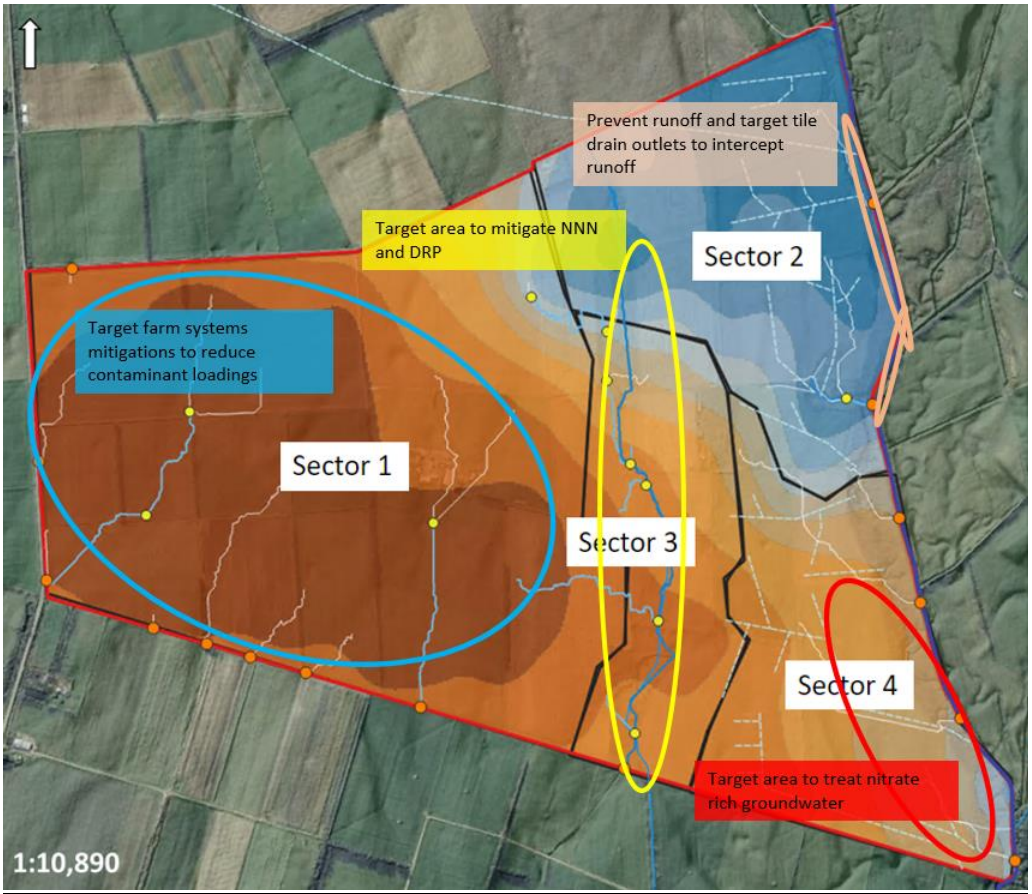

Figure 20 Farm map showing mitigations targeted to key susceptibility by sector.

Description

Sector 2 (43.5ha) consists of poorly-drained soils, remnant peat wetland and anoxic (stagnant) shallow groundwater adjacent to the Longridge Stream. Particulate and intermediate contaminants (ammoniacal nitrogen, dissolved organic N and P) is the main susceptibility. Runoff prevention and interception is the main focus.

Options to reduce/mitigate contaminate loss include:

- investigate tile drainage treatment options prior to discharge into the Longridge Stream, including wetland/sediment traps
- installation of sediment traps and detainment bunds to capture particulate phosphorus in runoff from this area.

There is an opportunity to fence off a 2ha area that is wet and of very low productivity and repurpose this into a wetland or sediment trap area with tile drains feeding into it and the adjacent plantation forest block. This would capture 85% of the water from sector 2. Using wetland performance estimates[17] the potential mitigation can be estimated.

[17] *Constructed Wetland Practitiioner Guide, Design and Performance Estimates, NIWA and DairyNZ*

Impact on environmental contaminants

Table 16 Install a 2ha wetland at the edge of sector 2 to treat water.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
No change	No change	5% decrease	No change	6% decrease

Compared with the year end 2023.

Planting the riparian area with deeper rooting plants to remove nitrate from the subsurface flow would provide further mitigation.

Farm system

The area retired has very low pasture productivity and is not suitable for arable cropping, therefore retiring it will have little impact on the farm system.

Financial impact

The cost of wetland establishment has not been calculated and will require a site-specific assessment. There is a rough estimated cost of $10,000 ($6,700 for wetland establishment and $3,300[18] for 500m of fencing).

Other impacts

The restoration of this area is likely to have positive impacts of restoration of mahinga kai.

[18] Ministry for Primary Industries Stock Exclusion Costs Report (January 2016). Electric 4 wire sheep fence on flat land @ $6.56 per m

7.1.6 Option 6, sector 3 – wetlands and sediment traps to treat nitrates and dissolved reactive phosphorus

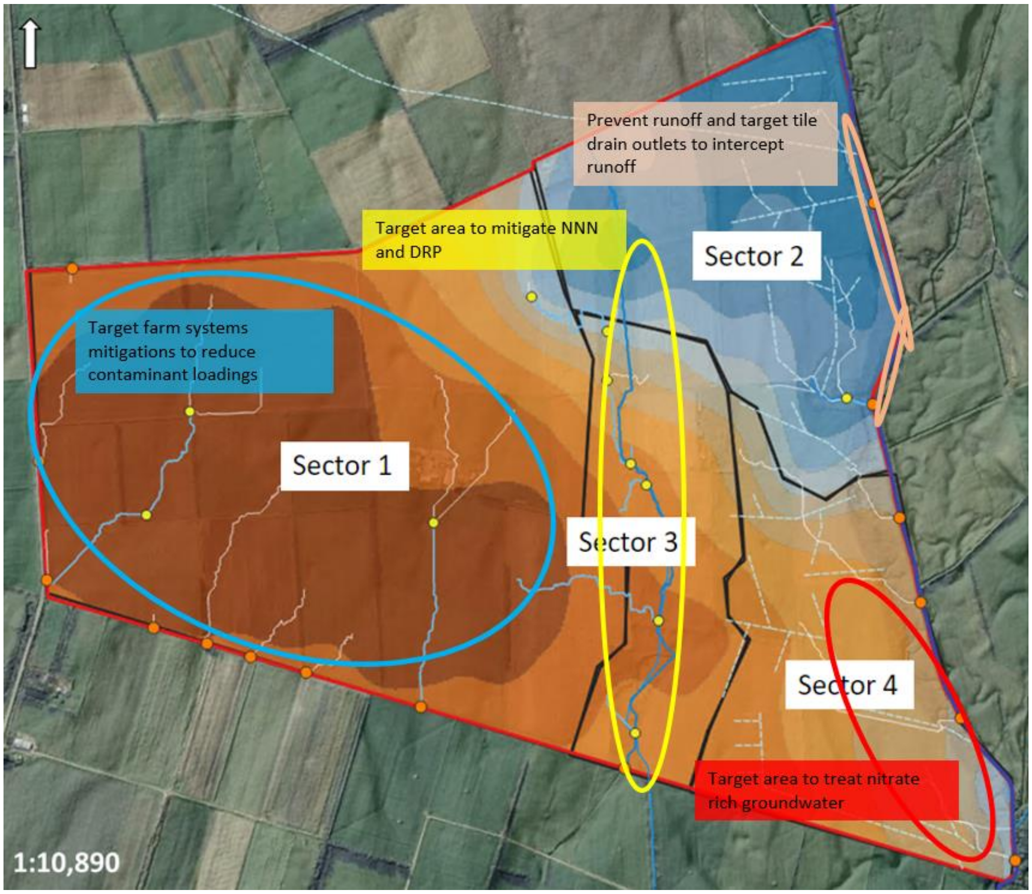

Figure 21 Farm map showing mitigations targeted to key susceptibility by sector.

Description

Sector 3 contains an ephemeral to intermittent stream that is associated with many small remnant wetlands. This will result in episodic runoff discharges to the Waimea stream to the South.

There is an opportunity to increase the size of the wetland and sediment trap at the bottom of sector 3. It is estimated this will capture water from 95% of the catchment area.

The current wetland area is 1.25ha and stock are not excluded. Increasing the area to 3.3ha and excluding stock would improve wetland performance. Using wetland performance estimates[19], the potential mitigation from a 3.3ha wetland that is functioning has been estimated in Table 17.

[19] *Constructed Wetland Practitioner Guide, Design and Performance Estimates, NIWA and DairyNZ.*

Impact on environmental contaminants

Table 17 Install a 3.3ha wetland in sector 3 to treat water.

Total GHG change	Nitrous oxide change	N loss change	N Surplus change	P loss change
No change	No change	9% decrease	No change	9% decrease

Compared with the year end 2023.

Farm system

The area retired for the wetland is outside of the plough lines currently used for cropping and is rarely grazed by stock, so very little impact on farm system.

Financial impact

The cost of wetland establishment has not been calculated and will require a site-specific assessment, however there is a rough estimated cost of $16,100 ($10,000 for wetland establishment and $6,100[20] for 930m of fencing).

Other impacts

This increase in area of wetlands and sediment traps would also treat water from properties that are upstream to this farm.

The restoration of this area is likely to have positive impacts of restoration of mahinga kai.

[20] Ministry for Primary Industries Stock Exclusion Costs Report (January 2016). Electric 4 wire sheep fence on flat land @ $6.56 per m

7.1.7 Option 7, sector 4 – develop wetland on lowest point of property to capture subsurface drains from a significant portion of the property

Description

Sector 4 consists of imperfectly drained soils, with significant fall across this sector. Subsurface drains intercept young, nitrate rich groundwater and discharge to the stream via the artificial drain network. There are options to intercept or block tile drains and let this revert to a groundwater-fed wetland system.

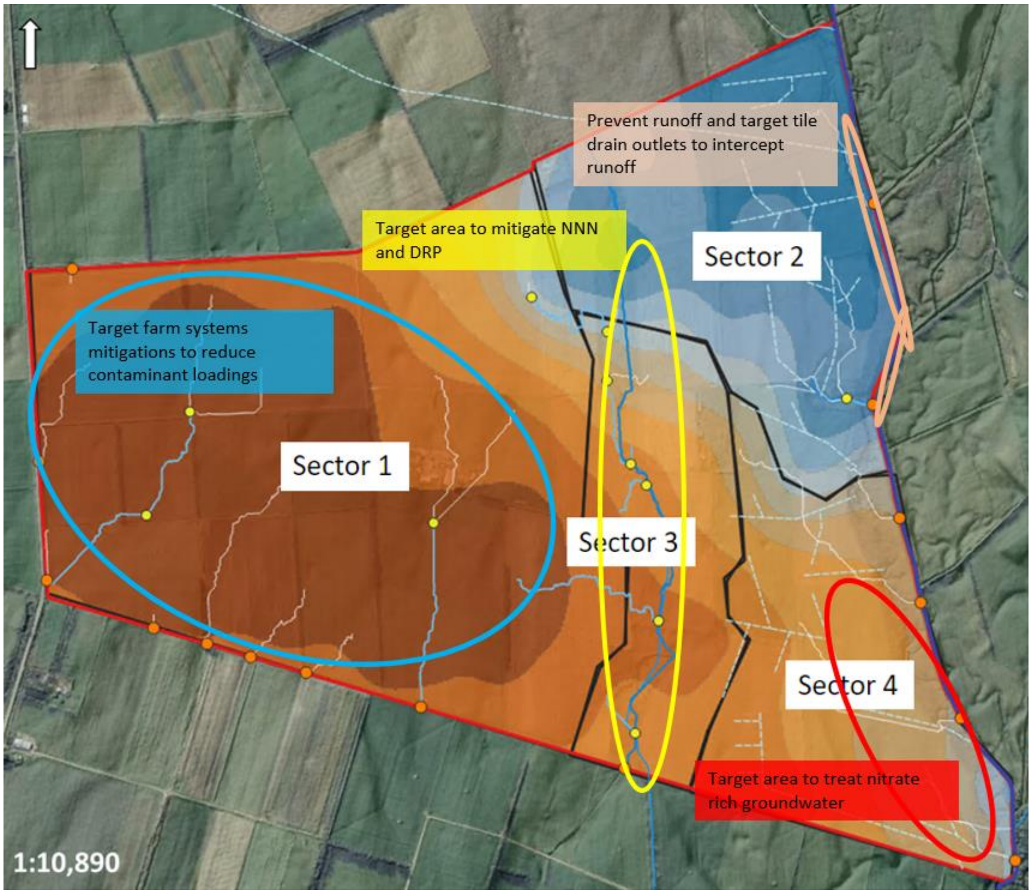

Figure 22 Farm map showing mitigations targeted to key susceptibility by sector.

The south-east corner of sector 4 is the lowest point of the property and it is estimated groundwater from most the property drains towards the corner in sector 4 (with water movement underneath sector 3).

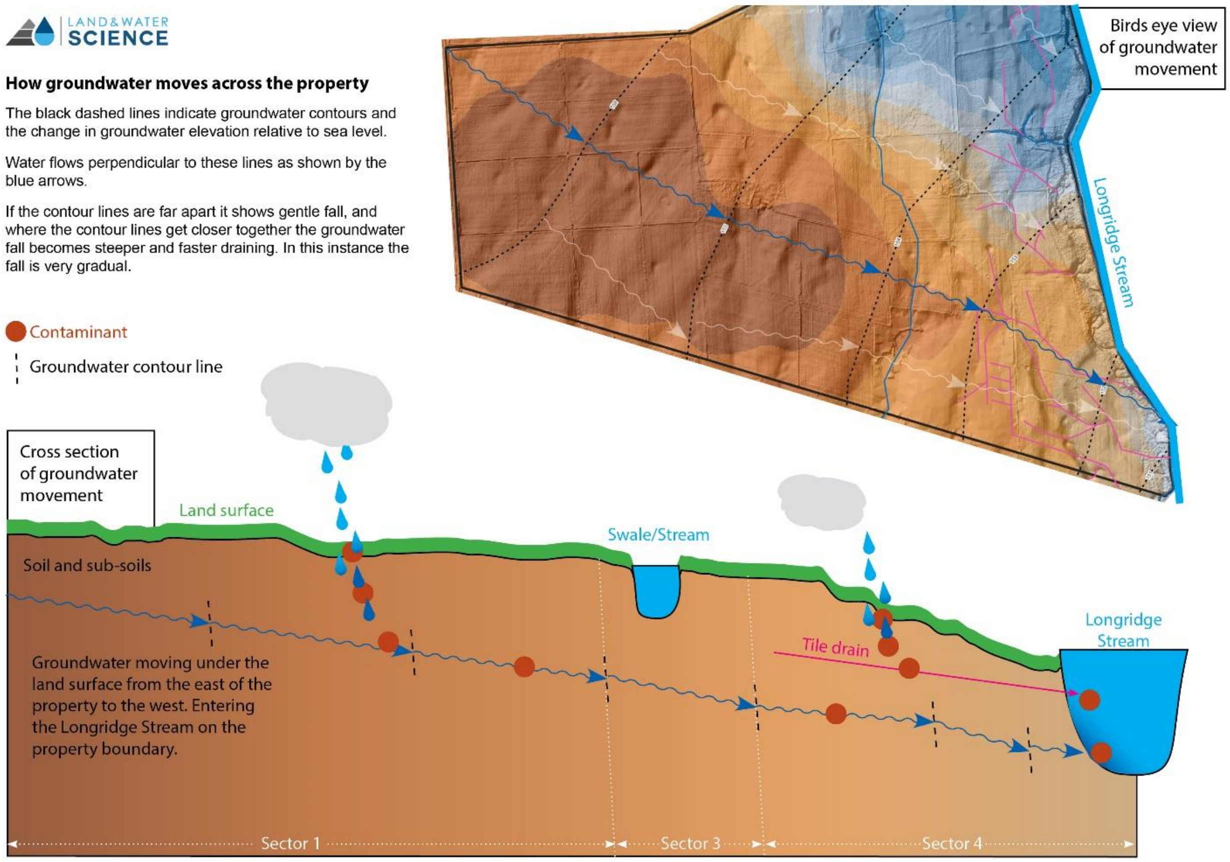

Figure 23 Groundwater movement across the property.

There is an opportunity to retire an area of land in sector 4 and repurpose into a 7.3ha sediment trap/ wetland system that is estimated to capture:

- 80% of shallow groundwater from sector 1
- 15% of shallow groundwater from sector 2
- 5% of shallow groundwater from sector 3 (the contribution from this area would mostly be from event-driven surface water movement – likely containing organic and ammoniacal N)
- 75% of shallow groundwater from sector 4.

The wetland has been sized to fit with existing fence lines of paddock 41. Using wetland performance estimates[21], the potential mitigation can be estimated.

[21] *Constructed Wetland Practitioner Guide, Design and Performance Estimates, NIWA and DairyNZ.*

Impact on environmental contaminants

Table 18 Install a 7.3ha wetland at the edge of sector 4, to treat water from the majority of the property.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
3% decrease	2% decrease	21% decrease	2% decrease	30% decrease

Compared with the year end 2023.

Farm system

Retired area of 7.3ha, mainly utilised for pasture grazing.

Financial impact

Currently this area is utilised for stock grazing and will need to be retired. The area to be retired is 7.3ha. Current revenue from grazing is approximately $1800 per hectare per annum. Retiring 7.3ha would reduce revenue by $13,140 per annum.

There would be minimal reduction in grazing-related expenses. No fencing would be required. A rough estimate for wetland establishment is $40,000 (digger work and some plants).

Other impacts

The restoration of this area is likely to have positive impacts of restoration of mahinga kai.

7.1.8 Option 8: Alternative land use to reduce contaminant loadings

Description

Sector 1 on the property has an extremely high risk of nitrate leaching, and land use change options are currently being explored. This is an increasing thought process for many New Zealand farmers.

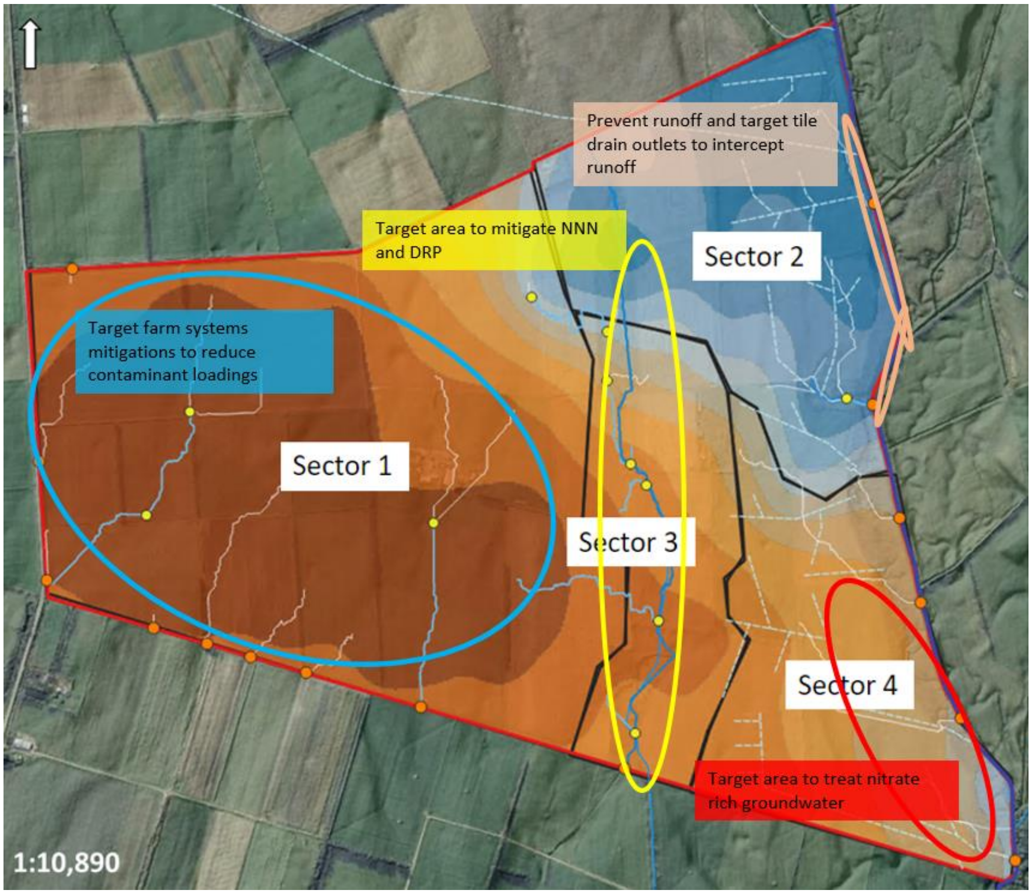

Figure 24 Farm map showing mitigations targeted to key susceptibility by sector.

"New Zealand is increasingly facing environmental and social challenges associated with its current land-use choices. Therefore there is a drive to find ways to continue to add value to its primary sectors, which are of significant economic value to the country while mitigating the externalities associated with the use of land in primary production[22].

[22] *Alan Renwick, Robyn Dynes, Paul Johnstone, Warren King, Lania Holt, Jemma Penelope (2022). Balancing the push and pull factors of land-use change: a New Zealand case study.*

Decision-making on land use change is complex[23] and factors that need to be considered include:

- **Knowledge base**
    - Current knowledge of new enterprise, the support available.

- **Financial**
    - Capital investment required, return on investment, profitability
    - The ability of the business to take on risk
    - Scalability.

- **Market factors**
    - Market scale
    - Market opportunities and returns
    - Is there an established stable market with consistent returns?
    - Strength of supply chain
    - Pathways to market – multiple options, or single seller controlled?
    - If an export product, what does the international market look like short medium and long-term?
    - If a new trend, what does the long-term market look like? e.g. plateau or growth.

- **Niche Products**
    - Niche or value add market
    - How is the market controlled, what are the risks from oversupply in the future?
    - Will provenance and brand protect against competition and market fluctuations?
    - Level of risk if it is a capital-intensive crop.

- **Regulations**
    - Environmental, animal welfare, building, food safety.

- **Social**
    - Wellbeing (local employment, quality of life, cultural values).

- **Environment**
    - Climate, biodiversity, contaminant loss, soils, disease).

The case study farmers are actively seeking alternative land use options that would ideally provide:

- opportunity for family engagement
- opportunity to be value add (rather than commodity)
- end product is of a high value in its use, but not seen as a luxury good
- set-up cost is not prohibitive to fund within current resources
- returns are higher than from the current land use
- target products for direct human use/consumption (rather than animal feeds)
- reduction in contaminant loadings and greenhouse gas emissions
- can be scaled up over time.

[23] *Alan Renwick, Robyn Dynes, Paul Johnstone, Warren King, Lania Holt, Jemma Penelope (2022). Balancing the push and pull factors of land-use change: a New Zealand case study.*

The case study farmers are comfortable with an entrepreneurial approach and are open to options that may take effort to develop markets. In discussions with the farmers, the following options have been considered:

- hazelnuts
- walnuts
- hops
- chestnuts.

Some information on these options have been summarised in Table 19. These are just some of the considerations, and a thorough business case should be undertaken before considering a substantial change.

Table 19 High level cost, returns and risks from hazelnuts, walnuts, hops and chestnuts.

	Capital cost	Returns	Risks	Market options	Other comments
Hazelnuts [24]	$8-25,000/ ha of establishment. 5 to 8 years to first crop (depending on variety).	Gross margin of $4200-$5000[25] per ha.	Timeframe to main crop: 5-8 years to first crop.	Existing and growing markets. Used in the commodity market.	Truffles are a potential companion crop to hazelnuts. Land that has previously been used for growing tulips may have fungicide residues that make it unsuitable. Low nitrogen use and deep rooting.
Walnuts[26]	Intial set-up $14,800/ ha. Capital cost of equipment $270,000. 8 years to economic return.	Gross margin $2800/ha[27] *(not including owner's labour).*	Puriri moths and hares can ring-bark trees, leaves are palatable to livestock and possums.	Strong US market with a high level of interest, due to health benefits. Can be processed for oil, flour, spreads as well as kernels.	Deep rooting. N applied only during main growing season in the spring.
Hops[28]	$60,000/ ha.	Gross margin of $21,000- $48,000.	Market fluctuations.	Local craft brewing market and export market.	Local processing facilities becoming available (Garston).

[24] *https://ruralleaders.co.nz/wp-content/uploads/2022/02/Lilley-George_A-Business-Case-for-Integrating-a-Hazelnut-Orchard-into-an-Existing-Arable-Farm.pdf*
https://truffleindustry.com.au/pests-diseases/.

[25] *Gross Margins for International Hazelnut Orchards (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012.*

[26] *https://www.nzherald.co.nz/the-country/news/new-zealand-walnut-industry-group-looking-to-bring-in-new-growers/YPDKH4ERV32RMYKTBIL27ZFJ6M/*
https://walnuts.org.nz/wp-content/uploads/2022/03/OpenDay-handout-FINAL-10Feb.pdf
https://www.unclejoes.co.nz/.

[27] *Walnut Open Day 12 February 2022 NZ Walnut Industry Group Inc. and Walnuts NZ Co-operative Ltd.*

[28] *https://www.venture.org.nz/assets/Uploads/Hops-Blueprint-Final.pdf.*

	Capital cost	Returns	Risks	Market options	Other comments
			Market currently being challenged with rapid growth. Craft beer a discretionary expenditure.		Minimum Viable area 40 ha, optimal 150ha.
Chestnuts [29]	$10,000/ ha. 3 to 4 years to first crop. 10 years to maturity.	Gross margin of $9,250 per ha[30].	Establishing trees (frost risk). Time to first crop. Market fluctuations.	New Zealand and international. Opportunity for value-add processing.	Well-suited to free-draining soils and Balfour climate. Considered low range for N loss. Reliable water supply needed during nut filling period.

[29] *https://landusenz.org.nz/chestnuts/#:~:text=Other%20products%20include%20chestnut%20fettuccine,for%20%2427%E2%80%9338%2Fkg*. *https://landuseopportunities.nz/dataset/chestnut-crop-suitability-maps-rules-and-yield-information.*

[30] *https://nzcc.org.nz/app/nzcc*

Of the above options, chestnuts were favoured for the following reasons:

- opportunity to start small and scale up
- lower establishment cost than the other options
- short to medium timeframe to first crop
- opportunity for value-add
- reject nuts could be utilised as an animal feed
- can use some existing equipment on the farm
- suited to the local soil and climate
- hardier species
- opportunity for family involvement.

The option modelled was land use change from 2ha of winter wheat to chestnuts. This aligned with the case study farmers' thinking of starting small and scaling up over time.

It should be noted there is no established value chain for chestnuts in New Zealand and considerable effort will be required to develop markets for the products.

"Overseas processed products include peeled frozen free-flow chestnuts, canned whole peeled chestnuts, vacuum-packed whole peeled chestnuts, icecream yoghurts, flour etc. Many products are sold on the health market for premium prices."

"Compared to many horticultural crops, a chestnut orchard is cheap to establish and maintain, and has a low input requirement (except at harvest). This allows most orchard owners to follow additional vocations as well."[31]

Impact on environmental contaminants

The area of land use changed to chestnuts was minor (less than 0.1%), therefore there was a correspondingly small impact on contaminant loss.

Table 20 Establish 2ha of chestnut trees (remove 2ha of winter wheat).

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
<1% decrease	1% decrease	1% decrease	2% decrease	No change

Compared with the year end 2022/23.

Notes

Apples were used as a proxy to model chestnuts in OverseerFM.
Assumed two applications of nitrogen (early spring and summer), a total of 23kg N/ ha/ yr.

[31] *Land Use Change Diversification in the Waikato. Waikato Regional Council Technical Report 2019/27. AgFirst Waikato.*

Farm system

Adding another crop/income diversifies the business but potentially adds more complexity of considering another crop, timing and marketing requirements.

Financial impact

The internal rate of return (IRR) for chestnuts is calculated at 18% (the IRR takes into account the time value of money). This compares with the current arable return (assuming winter wheat, the predominate crop) of 13.2%.

If 2ha of chestnut trees were planted, the peak capital requirement would be $21,000 and an 8 year payback period. Only a small scale 2ha has been modelled. It is assumed that minimum capital will be required to operate and predominately existing equipment and infrastructure can be utilised.

Scaling up to a larger operation would require investment into a packing shed and specialist harvesting equipment. For example, it is estimated that establishing a 10ha orchard taking into account increased capital investment, the IRR reduced to 9% and the payback period to 12.5 years.[32]

Assumptions

- Land value at $27500/ ha.
- Winter wheat
  - An annual return of $3632/ ha[33] from winter wheat.
  - No disposal of any plant and machinery with the slight reduction in winter wheat area.
- Chestnuts
  - Planting cost / establishment cost of chestnut trees of $10,000/ ha.
  - No irrigation required.
  - Plant and machinery investment for the chestnut operation of $10,000.
  - Annual maintenance and fertiliser cost for the chestnuts of $500/ ha until first harvest at year 4.
  - First harvest at year 4 – gross margin of $4625/ ha for years 4 to 6.
  - Gross margin of $6938 for years 7 to 9.
  - Gross margin of $9250 for years 10 and beyond.

Note

Further research and analysis is required to verify the financial information.

May need trickle irrigation but not at high rates.

[32] *Land Use Change Diversification in the Waikato. Waikato Regional Council Technical Report 2019/27. AgFirst Waikato.*
[33] *Enterprise Analysis, Gross Margins 2023, Lincoln University.*

7.2 Mitigation scenario – bundle of farm system, landscape and land use options

Farmers tend not to make one decision in isolation, they align multiple factors with their goals. This can result in multiple changes as they work towards achieving their goals.

The farmers want to understand, by aligning landscape features and the farm system, how much they could reduce their environmental impact within the current farm system. The bundle of options selected to achieve this are:

- **Option 1** – targeting nutrients applied to meet plant requirements and uptake (excluding land leased to tulips).
- **Option 2** – review crop rotations to reduce contaminant loadings (remove fallow period, remove winter fodder crop, add grass baleage).
- **Option 5** – sector 2: prevent runoff and target tile drain outlets to intercept runoff.
- **Option 6** – sector 3: develop 3.3ha of wetlands and sediment traps to treat nitrates and dissolved reactive phosphorus.
- **Option 7** – sector 4: develop 7.3ha wetland on the lowest point of property to capture subsurface drains from a significant portion of the property.

Impact on environmental contaminants

Table 21 Estimated impact of bundling mitigations

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
12% decrease	15% decrease	54% decrease	94% decrease	47% decrease

Compared with the year end 2023.

The predicted environmental impact has been calculated for the case study farmers' crops and does not include the land leased out for tulip growing. Fertiliser practices are not stipulated in the lease agreement.

Farm system

More time will need to be spent soil and plant testing, and using the information to inform decision-making.

If there is low growth in the summer/autumn (e.g. drought), there is a less assured supply of feed from pasture growth than a winter swede crop that has been established pre-Christmas.

The farm would need to build suitable pasture covers through autumn to ensure quality and quantity of feed through winter

Retired area of 7.3ha, mainly utilised for pasture grazing.

Financial impact

An increase in soil and plant testing costs and capital investment will be offset by a significant reduction in fertiliser expenditure.

Table 22 Partial budget for bundling mitigations.

Increase income None	Reduce income Retiring 7.3ha would reduce grazing revenue by $13,140 per annum.
Reduced costs Fertiliser savings (excluding tulip area) = $26,696. Reduced costs Costs associated with establishing winter crop (cultivation, seed, spray, fertiliser): 19.8ha at $1800/ ha = $35,640.	Increased costs Soil testing (soil mineral N), 26 samples at $70 per sample = $1820 Costs associated with establishment of short rotation (sowing [direct drilling] and seed): 19.8ha at $250/ ha = $4,950. Fertiliser required for short rotation = $10,650. Make an extra 490 bales of baleage at $45/ bale = $22,050. Capital cost of wetland establishment and fencing estimated at $66,100 at 8% interest = $5288 per annum.
$62,336	$57,898

An estimated cost saving to the case study farmer of $4438.

Note

The financial impact has been calculated for the case study farmers crops and does not include the costs of soil testing and fertiliser related to the land leased out for tulip growing.

Other impacts

The restoration of wetlands is likely to have positive impacts for mahinga kai. The increase in area of wetlands and sediment traps in Sector 3 would also treat water from properties that are upstream to this farm.

The following has not been calculated:

- The impact on future agricultural emissions pricing.

8 Conclusion

The main landscape susceptibility issue on the property is nitrate-nitrite-nitrogen (NNN) leaching associated with moderately well-drained shallow soils with gravelly subsoils associated with severe susceptibility to nitrate leaching. These soils overlie an oxidising aquifer that is susceptible to NNN accumulation.

The Balfour fan is a well-known 'nitrate hotspot'[34] due to the nature of the aquifer not being flushed by alpine or hill country water, therefore the concentrations of nitrate in some areas continue to build.

There are many options, both landscape and farm system, which could be implemented to reduce NNN losses from the farm to the underlying aquifer. Collectively, wetland systems combined with reducing farm system contaminant loadings offer the opportunity to reduce environmental contamination.

Specific options considered for this property were:

Table 23 Mitigation options.

		Net cost / benefit	**Total GHG change**	**Nitrous oxide change**	**N loss change**	**N surplus change**	**P loss change**
Option 1	Targeting nutrients applied to meet plant requirements and uptake (excluding area leased to tulips).	Increase in soil testing costs. Decrease in fertiliser cost. Overall $24,876 saving.	8% decrease	11% decrease	20% decrease	69% decrease	No change
Option 2	Review crop rotations to reduce contaminant loadings (remove fallow period, remove winter fodder crop, add grass baleage).	Increase of $2K in annual costs	3% increase	2% decrease	6% decrease	29% decrease	3% decrease
Option 3	Remove/sell crop residues (rather than retaining) on 41.6ha of	Need to replace nutrients removed in the sale of straw.	1.4% increase	2% decrease	1% increase	5% increase	No change

34 *https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/environment/water/groundwater/groundwater-monitoring/documents/groundwater-reports/balfour-nitrate-hotspot-2008.pdf*

		Net cost / benefit	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
	winter wheat.	Need pasture in rotation to maintain soil organic matter / structure. Increase revenue overall of $17,348. Highly dependent on markets and demand.					
Option 4	Use of low solubility phosphate fertilisers.	Increased cost in fertiliser of $7840.	No change	No change	No change	No change	6% decrease
Option 5	Sector 2 – prevent runoff and target tile drain outlets to intercept runoff.	Fencing cost – $3,300. Capital cost of wetland establishment of $6,700.	No change	No change	5% decrease	No change	6% decrease
Option 6	Sector 3 – 3.3ha of wetland and sediment traps to treat nitrates and dissolved reactive phosphorus.	Fencing cost – $6,100. Capital cost of wetland establishment of $10,000.	No change	No change	9% decrease	No change	9% decrease
Option 7	Sector 4 – develop wetland on lowest point of property to capture subsurface drains from a significant portion of the property.	Retire 7.3ha of land currently used for grazing, annual loss of income of $13,140. Capital cost of wetland establishment of $40,000.	3% decrease	2% decrease	21% decrease	2% decrease	30% decrease
Option 8	Alternative land use option to reduce contaminant loadings (establish 2ha of chestnuts).	Capital investment of $20,000 IRR of 18% (compared with winter wheat at 13%).	<1% decrease	1% decrease	1% decrease	2% decrease	No change

Bundling the most practical and cost-effective farm systems, landscape and land use options together

		Net cost / benefit	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
Scenario A	Targeting nutrients, review crop rotations, install wetlands and sediment traps.	Increase in soil testing costs. Decrease in fertiliser cost. Change in wintering costs. Decrease in grazing income. Capital cost of wetlands and fencing. Overall $4,438 saving.	12% decrease	15% decrease	54% decrease	94% decrease	47% decrease

Reducing current and future NNN losses requires consideration of the farm system and the timing of losses of NNN from the soil to the aquifer. Any activities that reduce NNN build up in the soil prior to the winter months, when water moves from the soil to the aquifer, will have a positive effect on water quality.

Collectively, a wetland system combined with efforts to reduce excess NNN in the soil prior to the winter months (when NNN is lost from the farm system) offers the greatest resilience.

It combines both landscape and land use decision-making to design a mitigation strategy that is directly targeting the environmental and regulatory risks to the property. The wetland system would also address issues of phosphorus, E. coli and soil nitrous oxide losses over the long-term, with the potential to sequester carbon as part of an offset.

Further reduction in environmental impact beyond what has been modelled is likely to require:

- further and new technologies (landscape and farm system)
- land use change to a less intensive farm system.

Appendices

Appendix 1 – state of the Mataura Catchment

Surface Water

There are 18 sites in the Mataura River Catchment where water quality is measured, with very good to good water quality in the upper catchment, which declines down catchment as the cumulative effects of land use activities take effect. Overall, surface water quality in the Mataura Catchment is characterised by elevated nitrogen, phosphorus, sediment, *E. coli* and degraded macroinvertebrate community index (MCI). A recent report by LWP estimated the nutrient load reductions required to meet catchment objectives are 79% for total nitrogen and 58% for total phosphorus[13]. The Mataura Freshwater Management Unit was the worst for suspended sediment with 61% of sites in D band (poor) in 2019 and only 35% of sites meeting visual clarity objectives[14].

Groundwater

The Waimea Plains Ground Water Management Zone (GMZ) has high nitrate levels near Balfour. Elevated nitrate concentrations in this area reflect a combination of the limited denitrification potential of overlying soils, combined with the slow rate of groundwater throughflow and lack of low nutrient recharge input from surface water.

An important issue affecting the Waimea Plains GWMZ is the 'Balfour Fan' immediately surrounding the southwest area of the Balfour township. The fan is an alluvial outwash surface deposited many years ago. The soils and shallow aquifer beneath parts of the fan are strongly oxidising, and naturally susceptible to elevated groundwater nitrate concentrations. In places, the soils of the fan are well-drained and highly weathered. Weathering removes some of the minerals and much of the organic matter that does often play a role in regulating nitrate build up in soil waters and aquifers. The highly weathered soils of the Balfour Fan overlie a weathered aquifer system. As a result, the groundwaters beneath parts of the Balfour Fan area are among the most strongly oxidising of the Southland region. Furthermore, as the aquifer beneath Balfour Fan is not flushed by alpine or hill country derived water, nitrate is able to build to high concentrations. Some of the groundwaters across the Balfour Fan have concentrations that exceed the New Zealand Drinking Water and WHO guidelines for nitrate toxicity to humans.

Toetoes Estuary

Currently the Toetoes Estuary where Mataura River discharges at Fortrose is considered to be in poor condition. Toetoes Estuary has areas currently assessed as D band (poor) for macroalgae, Gross Eutrophic Zone (GEZ), mud content and sediment oxygen levels. A recent NIWA report stated that most (~95%) of the nutrient load to the estuary comes from the Mataura River[15]. The nutrients from the Mataura River dominate the Mataura arm and lower estuary, but also supply ~ 38% of total nitrogen (TN) and total phosphorus (TP) in the Titiroa arm of the estuary. Overall, a reduction in nutrient and sediment inputs is needed to improve the estuary classification above D band (poor). Faecal bacteria also needs to be reduced to at least C band (fair) or better at the estuary monitoring sites.

[13] *Snelder, T. (2020). Assessment of Nutrient Load Reductions to Achieve Freshwater Objectives in the Rivers, Lakes and Estuaries of Southland Including Uncertainties: To inform the Southland Regional Forum process. Prepared for Environment Southland by Land and Water People.*

[14] *Norton, N., Wilson, K., Rodway, E., Hodson, R., Roberts, K. L., Ward, N., O'Connell-Milne, S., DeSilva, N., & Greer, M. (2019). Current environmental state and the "gap" to draft freshwater objectives for Southland. Environment Southland Technical Report, 12.*

reduction in nutrient and sediment inputs is needed to improve the estuary classification above D band (poor). Faecal bacteria also needs to be reduced to at least C band (fair) or better at the estuary monitoring sites.

[15] *Plew, D., Dudley, B., Shankar, U. (2020) Eutrophication susceptibility assessment of Toetoes (Fortrose) Estuary. NIWA Client Report, 2020070CH: 58.*

Appendix 2

Table 24 Good management practice fertiliser applications (rate and timing).

Crop	Fert amount/ rate	Timing	GMP	Comments
Winter wheat[35]	25kg N/ tonne of grain yield produced.	40kg N early spring, 2/3 of the remainder of N at Growth Stage 32 (GS32) & 1/3 of N at GS39.	Actual amount applied depends on yield potential and soil mineral N (soil minN) + potentially mineralisable N (PMN). Timing of application is important, as late application can delay maturation.	Spring sown crops usually get N at sowing and GS32.
Barley[36]	25kg N/ tonne of grain yield produced.	40kg N early spring, 2/3 of the remainder at GS32 & 1/3 GS39.	Same as for wheat above.	1. Spring sown crops usually gets N at sowing and GS32. 2. Lower for malting barley (20kg N/ ton grain yield).

[35] *FAR Cropping Strategies - Nitrogen application in wheat (Issue 1; 2011).*

[36] *FAR Arable Extra - Nitrogen removal by cereals and maize crops (No. 15; September 1996).*

Crop	Fert amount/ rate	Timing	GMP	Comments
Oats[37]	23kg N/ tonne of grain yield produced.	N depleted soils will need about 10-15 kg N/ha at sowing. Early application is recommended, GS10s. [Always before tillering]	Same as for wheat and barley.	No yield differences between 50kg N/ha at GS13 vs. 100kg N/ha split between GS13 & 40.
Kale and swedes[38]	15kg N/ tonne of biomass produced.	Starter N (40-50 kg/ha) at sowing and then split the remaining N at 6 and 12 weeks after sowing.	Actual amount applied depends on yield potential and soil minN.	Use the **Ballance Agri-Nutrient** Brassica calculator if accessible.
Lucerne[39]	None	None	Lucerne fixes N for its own needs.	Current recommendations are not to apply N fertilisers, as lucerne crops fix their own N.
Tulips[40]	45-80kg N/ha.	Study in New Zealand for tulips grown following pasture shows that they did not need any additional fertiliser N if there is a high soil min N after pastures.	Actual amounts of N applied depends on background soil N, and its potential to mineralize N (or PMN).	Usually sown in early autumn and harvested in late summer.

[37] *FAR Arable Extra – Oats crop management guide (No. 16; March 1997).*

McBeath, D. K., & Toogood, J. A. (1960). The effects of nitrogen top dressing on yield and protein content of nitrogen deficient cereals. Canadian Journal of Soil Science, 40(2), 130-135. https://doi.org/10.4141/cjss60-018.

Daly, M. J., & Martin, R. J. (1988). Oilseed rape: Th eeffects of rate, timing and form of nitrogen applications on a depleted Lismore soil. Agronomy New Zealand, 18, 97-102.

Welch, R. W., & Yong, Y. Y. (1980). The effects of variety and nitrogen fertiliser on protein production in oats. Journal of the Science of Food and Agriculture, 31(6), 541-548.

[38] *Fertiliser Use on New Zealand Forage Crops, Fertiliser Association.*

[39] [6]*Russelle, M., Lamb, J., Turyk, N., Shaw, B., & Pearson, B. (2007). Managing Nitrogen Contaminated Soils: Benefits of N2-Fixing Alfalfa. Agronomy Journal, 99, 738-746. https://doi.org/10.2134/agronj2006.0325.*

[6]*Derrick Moot, Lincoln University (Personal Communication).*

[40] [7]*Khaembah, E. N., Cichota, R., Brown, H. E., Fraser, T. P., & Freeman, M. (2022). Modelling nitrogen losses during pasture renewal in Edendale, Southland, New Zealand.Adaptive strategies for future farming Farmed Landscapes Research Centre (flrc), Massey University, Palmerstone North.*

Crop	Fert amount/ rate	Timing	GMP	Comments
Oilseed rape[41]	50-60kg N/ tonne of seed produced.	At sowing and stem extension.	Actual amounts applied depends on background soil N.	Although seed/yield increases with increasing N application, the oil yield (%) decreases with increasing N.
Peas[42]	None	None	Peas fix own N.	Current recommendations are not to apply N fertilisers, as peas fixes their own N.

[41] *Rathke, G. W., Behrens, T., & Diepenbrock, W. (2006). Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (Brassica napus L.): A review. Agriculture, Ecosystems and Environment, 117, 80-108.* *http://ac.els-cdn.com/S0167880906001472/1-s2.0-S0167880906001472-main.pdf?_tid=b7502062-cdc6-11e4-b8e9-00000aacb35d&acdnat=1426721589_5b466839136e8bfa990e6a7765bb2fed*
Boelcke, B., Léon, J., Schulz, R. R., Schröder, G., & Diepenbrock, W. (1991). Yield Stability of Winter Oil-Seed Rape (Brassica napus L.) as Affected by Stand Establishment and Nitrogen Fertilization. Journal of Agronomy and Crop Science, 167(4), 241-248. *https://doi.org/https://doi.org/10.1111/j.1439-037X.1991.tb00870.x.*
FAR Arable (No. 23) (1997) – Soil & Fertilisers (Nitrogen requirements for oil seed rape)
Sidlauskas, G., & Tarakanovas, P. (2004). Factors affecting nitrogen concentration in spring oilseed rape (Brassica napus L.). *Plant, Soil and Environment*, *50*(5), 227-234. https://pse.agriculturejournals.cz/artkey/pse-200405-0006.php

Chakwizira, E., Fletcher, A. L., George, M., & Trethewey, J. (2010). Growth, development and seed yield of autumn forage rape in response to sowing dates and sowing rates. Proceedings of the Agronomy Society of New Zealand, 40, 119-132.

[42] *Horrocks, A. J., Johnstone, P.R., Maley, S., Meenken, E.D. (2015). Quantifying the supply of nitrogen from summer legumes to autumn-sown wheat. A Plant & Food Research report prepared for: Foundation for Arable Research. Milestone No. 52801. Contract No. 29576. Job code: P/442045/02. SPTS No. 11762. 39.*
Wilson, D. R., Tregurtha, C. S., Williams, P. H., & Curtin, D. (1999). Yield responses of field and process peas to fertiliser application. Agronomy New Zealand, 29, 17-22.